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United States Department of Agriculture
Natural Resources Conservation Service

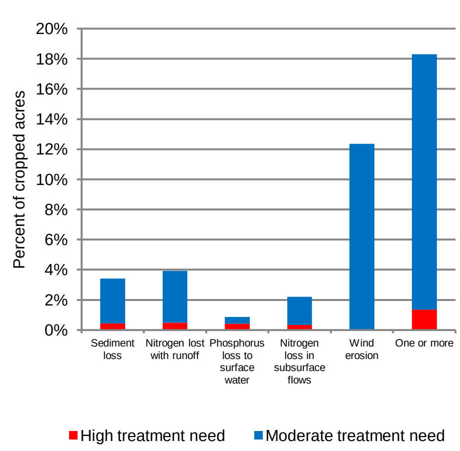
Conservation Effects
Assessment Project
(CEAP)

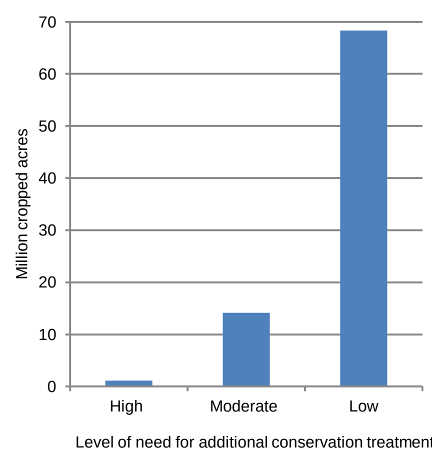
JUNE 2012

Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Missouri River Basin









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Cover photos by (clockwise from top left): **Bob Nichols, Don Poggensee, Jerry Walker,** and **Jeff Vanuga**, USDA Natural Resources Conservation Service.

CEAP—Strengthening the science base for natural resource conservation

The Conservation Effects Assessment Project (CEAP) was initiated by USDA's Natural Resources Conservation Service (NRCS), Agricultural Research Service (ARS), and Cooperative State Research, Education, and Extension Service (CSREES—now National Institute of Food and Agriculture [NIFA]) in response to a general call for better accountability of how society would benefit from the 2002 Farm Bill's substantial increase in conservation program funding (Mausbach and Dedrick 2004). The original goals of CEAP were to estimate conservation benefits for reporting at the national and regional levels and to establish the scientific understanding of the effects and benefits of conservation practices at the watershed scale. As CEAP evolved, the scope was expanded to provide research and assessment on how to best use conservation practices in managing agricultural landscapes to protect and enhance environmental quality.

CEAP activities are organized into three interconnected efforts:

- *Bibliographies, literature reviews, and scientific workshops* to establish what is known about the environmental effects of conservation practices at the field and watershed scale.

- *National and regional assessments* to estimate the environmental effects and benefits of conservation practices on the landscape and to estimate conservation treatment needs. The four components of the national and regional assessment effort are *Cropland*; *Wetlands*; *Grazing lands*, including rangeland, pastureland, and grazed forest land; and *Wildlife*.

- *Watershed studies* to provide in-depth quantification of water quality and soil quality impacts of conservation practices at the local level and to provide insight on what practices are the most effective and where they are needed within a watershed to achieve environmental goals.

Research and assessment efforts were designed to estimate the effects and benefits of conservation practices through a mix of research, data collection, model development, and model application. A vision for how CEAP can contribute to better and more effective delivery of conservation programs in the years ahead is addressed in Maresch, Walbridge, and Kugler (2008). Additional information on the scope of the project can be found at http://www.nrcs.usda.gov/technical/nri/ceap/.

This report was prepared by the Conservation Effects Assessment Project (CEAP) Cropland Modeling Team and published by the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). The modeling team consists of scientists and analysts from NRCS, the Agricultural Research Service (ARS), Texas AgriLife Research, and the University of Massachusetts.

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Acknowledgements

The team thanks Al**ex Barbarika**, **Rich Iovanna**, and **Skip Hyberg** USDA-Farm Service Agency, for providing data on Conservation Reserve Program (CRP) practices and making contributions to the report; **Harold Coble and Danesha Carley**, North Carolina State University, for assisting with the analysis of the integrated pest management (IPM) survey data; **Dania Fergusson, Eugene Young,** and **Kathy Broussard**, USDA-National Agricultural Statistics Service, for leading the survey data collection effort; **Mark Siemers** and **Todd Campbell**, CARD, Iowa State University, for providing I-APEX support; **NRCS field offices** for assisting in collection of conservation practice data; **Dean Oman**, USDA-NRCS, Beltsville, MD, for geographic information systems (GIS) analysis support; **Melina Ball**, Texas AgriLife Research, Temple, TX, for HUMUS graphics support; **Peter Chen, Susan Wallace, George Wallace, and Karl Musser,** Paradigm Systems, Beltsville, MD, for graphics support, National Resources Inventory (NRI) database support, Web site support, and calculation of standard errors; and many others who provided advice, guidance, and suggestions throughout the project.

The team also acknowledges the many helpful and constructive suggestions and comments by reviewers who participated in the peer review of earlier versions of the report.

Foreword

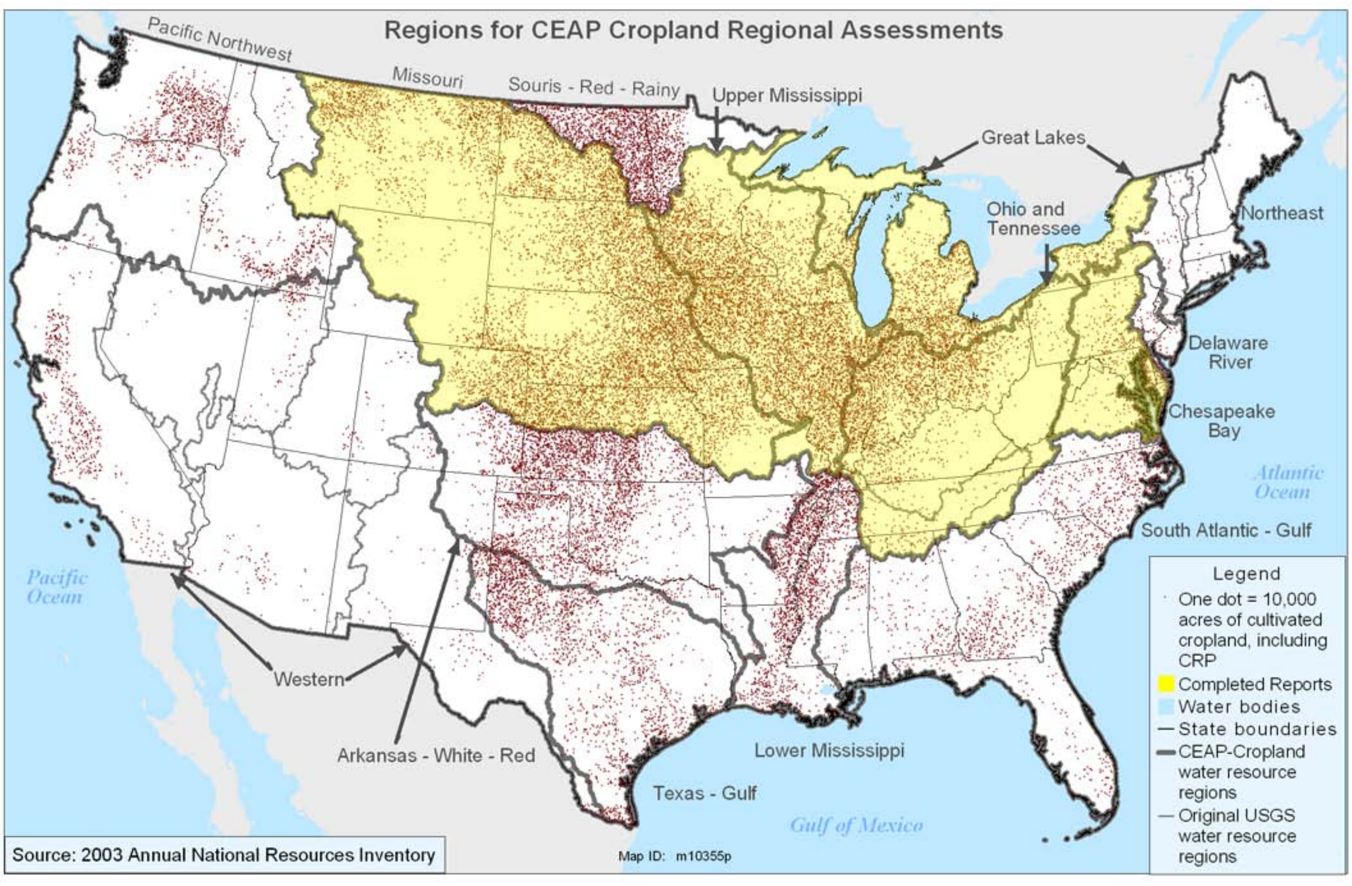
The United States Department of Agriculture has a rich tradition of working with farmers and ranchers to enhance agricultural productivity and environmental protection. Conservation pioneer Hugh Hammond Bennett worked tirelessly to establish a nationwide Soil Conservation Service along with a system of Soil and Water Conservation Districts. The purpose of these entities, now as then, is to work with farmers and ranchers and help them plan, select, and apply conservation practices to enable their operations to produce food, forage, and fiber while conserving the Nation's soil and water resources.

USDA conservation programs are voluntary. Many provide financial assistance to producers to help encourage adoption of conservation practices. Others provide technical assistance to design and install conservation practices consistent with the goals of the operation and the soil, climatic, and hydrologic setting. By participating in USDA conservation programs, producers are able to—

- install structural practices such as riparian buffers, grass filter strips, terraces, grassed waterways, and contour farming to reduce erosion, sedimentation, and nutrients leaving the field;
- adopt conservation systems and practices such as conservation tillage, comprehensive nutrient management, integrated pest management, and irrigation water management to conserve resources and maintain the long-term productivity of crop and pasture land; and
- retire land too fragile for continued agricultural production by planting and maintaining on them grasses, trees, or wetland vegetation.

Once soil conservation became a national priority, assessing the effectiveness of conservation practices also became important. Over the past several decades, the relationship between crop production and the landscape in which it occurs has become better understood in terms of the impact on sustainable agricultural productivity and the impact of agricultural production on other ecosystem services that the landscape has potential to generate. Accordingly, the objectives of USDA conservation policy have expanded along with the development of conservation practices to achieve them.

The Conservation Effects Assessment Project (CEAP) continues the tradition within USDA of assessing the status, condition, and trends of natural resources to determine how to improve conservation programs to best meet the Nation's needs. CEAP reports use a sampling and modeling approach to quantify the environmental benefits that farmers and conservation programs are currently providing to society, and explore prospects for attaining additional benefits with further conservation treatment. CEAP findings are being released in a series of regional reports for the regions shown in the following map.



Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Missouri River Basin

Contents

Documentation Reports

There are a series of documentation reports and associated publications by the modeling team posted on the CEAP website at: http://www.nrcs.usda.gov/technical/nri/ceap. (Click on "Cropland" and then click on "documentation reports and associated publications.") Included are the following reports that provide details on the modeling and databases used in this study:

- The HUMUS/SWAT National Water Quality Modeling System and Databases
- Calibration and Validation of CEAP-HUMUS
- Delivery Ratios Used in CEAP Cropland Modeling
- APEX Model Validation for CEAP
- Pesticide Risk Indicators Used in CEAP Cropland Modeling
- Integrated Pest Management (IPM) Indicator Used in CEAP Cropland Modeling
- NRI-CEAP Cropland Survey Design and Statistical Documentation
- Transforming Survey Data to APEX Model Input Files
- Modeling Structural Conservation Practices for the Cropland Component of the National Conservation Effects Assessment Project
- APEX Model Upgrades, Data Inputs, and Parameter Settings for Use in CEAP Cropland Modeling
- APEX Calibration and Validation Using Research Plots in Tifton, Georgia
- The Agricultural Policy Environmental EXtender (APEX) Model: An Emerging Tool for Landscape and Watershed Environmental Analyses
- The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Directions
- Historical Development and Applications of the EPIC and APEX Models
- Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for the CEAP National Cropland Assessment
- Manure Loadings Used to Simulate Pastureland and Hayland in CEAP HUMUS/SWAT modeling
- Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling

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Executive Summary

Agriculture in the Missouri River Basin

The Missouri River Basin is the largest of the water resource regions that make up the Mississippi River drainage. The basin covers about 510,000 square miles and extends from the continental divide and southern Canada through the northern Great Plains and discharges into the Mississippi River just north of St. Louis, MO. The basin includes all of Nebraska and parts of Colorado, Iowa, Kansas, Minnesota, Missouri, Montana, North Dakota, South Dakota, and Wyoming.

Agricultural land makes up most of the area—29 percent cultivated cropland, 3 percent permanent hay land, and 52 percent grazing land (pasture and rangeland). Even though cultivated cropland is not the dominant land cover, the amount of cultivated cropland—95 million acres—is about equal to the amount of cultivated cropland in the Upper Mississippi River Basin and the Ohio-Tennessee River Basin combined. Only about 3 percent of the basin area is urban land. Forestland makes up most of the remaining 13 percent.

Agriculture is vital to the economy of the region. The Missouri River Basin accounted for about 15 percent of all U.S. crop sales in 2007, totaling $22 billion, and about 17 percent of all U.S. livestock sales, totaling $27 billion. Farms in the Missouri River Basin make up about 28 percent of all land on farms in the Nation. Corn and soybeans are the principal crops grown in the eastern portion of the basin and wheat and other small grain crops are the principal crops grown in the western portion. Livestock sales in the region are dominated by cattle sales, which represented 32 percent of all cattle sales nationally in 2007. Hog and pig sales are also important, representing 23 percent of national sales.

The 2007 Census of Agriculture reported that there were about 268,000 farms in the region—12 percent of the farms in the United States. The average farm in this region is much larger than in most other areas of the country—959 acres. Farms with total agricultural sales greater than $250,000 accounted for 20 percent of the farms. About 57 percent of the farms primarily raise crops, about 32 percent are primarily livestock operations, and the rest produce a mix of livestock and crops.

Agriculture in this region is not as inherently productive as in the Upper Mississippi River Basin or the Ohio-Tennessee River Basin because of lower precipitation and generally less fertile soils. Precipitation in the Missouri River Basin averages 23 inches per year, compared to 34 inches per year in the Upper Mississippi River Basin and 42 inches per year in the Ohio-Tennessee River Basin. In the western portion of the region, precipitation averages only 18 inches per year. About 14 percent of cropped acres are irrigated in the Missouri River Basin, 11 percent in the eastern portion of the basin and 17 percent in the western portion.

Focus of CEAP Study Is on Edge-Of-Field Losses from Cultivated Cropland

The primary focus of the CEAP Missouri River Basin study is on the 29 percent of the basin that is cultivated cropland. The study was designed to—

- quantify the effects of conservation practices commonly used on cultivated cropland in the Missouri River Basin during 2003–06,
- evaluate the need for additional conservation treatment in the region on the basis of wind erosion and edge-of-field sediment and nutrient losses, and
- estimate the potential gains that could be attained with additional conservation treatment.

The assessment uses a statistical sampling and modeling approach to estimate the effects of conservation practices. The National Resources Inventory (NRI), a statistical survey of conditions and trends in soil, water, and related resources on U.S. non-Federal land conducted by USDA's Natural Resources Conservation Service, provides the statistical framework for the study. Physical process simulation models were used to estimate the effects of

conservation practices that were in use during the period 2003–06. Information on farming activities and conservation practices was obtained primarily from a farmer survey conducted as part of the study. The assessment includes not only practices associated with Federal conservation programs but also the conservation efforts of States, independent organizations, and individual landowners and farm operators. The analysis assumes that structural practices (such as buffers, terraces, and grassed waterways) reported in the farmer survey or obtained from other data sources were appropriately designed, installed, and maintained.

The national sample for the farmer survey consists of 18,700 sample points with 3,916 of these sample points located in the Missouri River Basin. This sample size is sufficient for reliable and defensible reporting at the regional scale and for most of the 29 subregions, but is generally insufficient for assessments of smaller areas.

The modeling strategy for estimating the effects of conservation practices consists of two model scenarios that are produced for each sample point.

1. A baseline scenario, the “baseline conservation condition” scenario, provides model simulations that account for cropping patterns, farming activities, and conservation practices as reported in the NRI-CEAP Cropland Survey and other sources.
2. An alternative scenario, the “no-practice” scenario, simulates model results as if no conservation practices were in use but holds all other model inputs and parameters the same as in the baseline conservation condition scenario.

The effects of conservation practices are obtained by taking the difference in model results between the two scenarios. The need for additional conservation treatment was evaluated using a common set of criteria and protocols applied to all regions in the country to provide a systematic, consistent, and comparable assessment at the national level.

Voluntary, Incentives-Based Conservation Approaches Are Achieving Results

Given the long history of conservation in the Missouri River Basin, it is not surprising to find that nearly all cropped acres in the region have some conservation practice use, including both soil erosion control practices and nutrient management practices on most acres. Model results show that farmers in the Missouri River Basin have made substantial progress in reducing sediment, nutrient, and pesticide losses from farm fields through conservation practice adoption. Because of the relatively low annual precipitation in this region and the widespread use of soil erosion control practices, nutrient management practices, and increased irrigation efficiencies, the per-acre losses at the field level throughout most of this region are lower than in other regions, with the important exception of wind erosion.

Conservation Practice Use

The farmer survey found, for the period 2003–06, that producers use either residue and tillage management practices or structural practices, or both, on 98 percent of the acres.

- Structural practices for controlling water erosion are in use on 41 percent of cropped acres. Forty percent of cropped acres are designated as highly erodible land; structural practices designed to control water erosion are in use on 37 percent in the western portion of the region and 73 percent in the eastern portion.
- Structural practices for controlling wind erosion are in use on 10 percent of cropped acres.
- Reduced tillage is common in the region; 46 percent of the cropped acres meet criteria for no-till and 47 percent meet criteria for mulch till. All but 3 percent of the acres had evidence of some kind of reduced tillage on at least one crop in the rotation.

The farmer survey also found that nutrient management practices are frequently used on cropped acres in the Missouri River Basin. Nutrient management practices are more prevalent in the Missouri River Basin than in the Upper Mississippi River Basin or the Ohio-Tennessee River Basin, with more than 60 percent of the acres meeting criteria for high or moderately high levels of nitrogen or phosphorus management. In the Missouri River Basin, cropping systems are less intensely fertilized with lower application rates, drier planting seasons, and more crops harvested during the summer.

- Appropriate *timing* of nitrogen applications is in use on about 72 percent of the acres for all crops in the rotation, and appropriate *timing* of phosphorus applications is in use on about 75 percent of the acres for all crops in the rotation.

- Appropriate *methods* of nitrogen application are in use on about 61 percent of the acres for all crops in the rotation, and appropriate *methods* of phosphorus application are in use on about 70 percent of the acres for all crops in the rotation.
- Appropriate *rates* of nitrogen application are in use on about 62 percent of the acres for all crops in the rotation, and appropriate *rates* of phosphorus application are in use for the crop rotation on about 41 percent of the acres.
- Although most cropped acres meet nutrient management criteria for rate, timing, or method, fewer acres meet criteria for all three:
  - 35 percent of cropped acres meet all criteria for nitrogen applications;
  - 41 percent of cropped acres meet all criteria for phosphorus applications; and
  - 24 percent of cropped acres meet criteria for *both* phosphorus and nitrogen.

About 60 percent of cropped acres are gaining soil organic carbon (that is, the average annual change in soil organic carbon is greater than zero), including 84 percent of cropped acres in the eastern portion of the region and 42 percent in the western portion.

Land in long-term conserving cover, as represented by enrollment in the Conservation Reserve Program (CRP) General Signup, consists of about 11.2 million acres—12 percent of the cultivated cropland acres in the region. About 72 percent of the land in long-term conserving cover is highly erodible.

Conservation Accomplishments at the Field Level

Compared to a model scenario without conservation practices, field-level model simulations showed that conservation practice use during the period 2003–06 has—

- reduced wind erosion by 58 percent;
- reduced waterborne sediment loss from fields by 73 percent;
- reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 58 percent;
- reduced nitrogen loss in subsurface flows by 45 percent;
- reduced total phosphorus loss (all loss pathways) from fields by 58 percent;
- reduced pesticide loss from fields to surface water, resulting in a 45-percent reduction in edge-of-field pesticide risk (all pesticides combined) for humans and a 64-percent reduction for aquatic ecosystems; and
- increased the percentage of cropped acres gaining soil organic carbon from 46 to 60.

Use of improved irrigation systems in the Missouri River Basin increases irrigation efficiency from 50 percent in the no-practice scenario to 69 percent in the baseline scenario. This change in efficiency represents an annual decreased need for irrigation water of 6 inches per year where irrigation is used.

At 11.2 million acres, land in long-term conserving cover (CRP) is an important part of the agricultural landscape in the Missouri River Basin. The benefits of this conservation practice were estimated by simulating crop production on these acres without use of conservation practices. Model simulation results show that soil erosion and sediment loss have been almost completely eliminated for land in long-term conserving cover. Total nitrogen loss has been reduced by 81 percent, total phosphorus loss has been reduced by 99 percent, and soil organic carbon has been increased by an average of 192 pounds per acre per year compared to a cropped condition without conservation practices.

Conservation Accomplishments at the Watershed Level

Reductions in field-level losses due to conservation practices are expected to improve water quality in streams and rivers in the region. Transport of sediment, nutrients, and pesticides from farm fields to streams and rivers involves a variety of processes and time-lags, and not all of the potential pollutants leaving fields contribute to instream loads. Edge-of-field losses of sediment, nitrogen, phosphorus, and the pesticide atrazine were incorporated into a national water quality model to estimate the extent to which conservation practices have reduced amounts of these contaminants delivered to rivers and streams throughout the region. Of the total loads <u>delivered to rivers and streams</u> from all sources, cultivated cropland is the source for 72 percent of the sediment, 68 percent of the nitrogen, and 46 percent of the phosphorus.

The model simulations showed that conservation practices in use during the period 2003–06, including land in long-term conserving cover, have reduced average annual loads <u>delivered to rivers and streams</u> within the basin,

compared to a no-practice scenario, by 76 percent for sediment, 54 percent for nitrogen, 60 percent for phosphorus, and 36 percent for atrazine. The national water quality model also provided estimates of reductions in ***instream loads*** due to conservation practice use. *When considered along with loads from all other sources*, conservation practices in use on cultivated cropland in 2003–06 have reduced total instream loads delivered from this region to the Mississippi River by—

- 4 percent for sediment,
- 36 percent for nitrogen,
- 28 percent for phosphorus, and
- 32 percent for atrazine.

The percent reduction for sediment loads delivered to the Mississippi River is low because of the system of reservoirs along the Missouri River. The Missouri Basin has six major reservoirs that trap significant amounts of sediment, nitrogen, and phosphorus delivered from cultivated cropland to rivers and streams. Downstream of these reservoirs there is significant streambank and streambed erosion, further limiting the impact of upstream conservation practices on sediment loads delivered to the Mississippi River.

Emerging Conservation Challenges for the Missouri River Basin

Dramatic changes are underway in some parts of this region—land use conversion, changes in crops and cropping systems, and increased subsurface drainage and tillage of croplands. Maintaining the gains in conservation as represented by the 2003–06 survey will be a challenge in the face of rising commodity prices and expansion of cropped acreage. Some of these emerging conservation challenges are—

- Cultivated acres are increasing in the region as farmers expand their operations in response to the increased demand for food and fuel crops. In some areas, this expansion has resulted in "sodbusting"—cultivation of previously uncultivated acres.
- Acres in the Conservation Reserve Program (CRP) are increasingly being converted back to cultivation rather than being re-enrolled in the program. The majority of these acres are highly erodible. CRP acres converted back to cultivation will require appropriate suites of conservation practices to minimize environmental impacts.
- Where climate allows, crop mixes are shifting to continuous row cropping (corn and soybeans primarily) and away from the close-grown crops that provide more protection against wind and water erosion. In some areas, climate change has extended the growing season sufficiently to allow more production of row crops.
- Water use efficiency is an ongoing necessity in many parts of the region in order to maintain current levels of crop production.
- Expansion of subsurface drainage, if not accompanied by comprehensive nutrient management practices (timing, method, form, and rate of application) could significantly increase amounts of nitrogen and soluble phosphorus lost from farm fields through subsurface flow pathways.
- The more permanent conservation practices (terraces, wind barriers, and irrigation systems) which predominate in this region have a life span that will require continued maintenance and eventual replacement.

Opportunities Exist to Further Reduce Soil Erosion and Nutrient Losses from Cultivated Cropland

The assessment of conservation treatment needs presented in this study identifies significant opportunities to further reduce contaminant losses from farm fields. The study found that 15.3 million acres (18 percent of cropped acres) have a **high** or **moderate** level of need for additional conservation treatment. Acres with a **high** level of need (1.1

million acres) consist of the most vulnerable acres with the least conservation treatment and the highest losses of sediment or nutrients. Acres with a **moderate** level of need (14.2 million acres) consist of under-treated acres that generally have lower levels of vulnerability or have more conservation practice use than acres with a **high** level of need but still have unacceptable levels of soil erosion or nutrient loss at the field level.

The climatic differences across the region influence the kinds of agriculture and the conservation treatment needs. The eastern portion of the basin has higher annual precipitation and supports cropping systems similar to those in the Upper Mississippi River Basin. In this portion of the region, most of the under-treated acres are for resource concerns associated with water runoff. In the drier western portion of the basin, cropping systems are dominated by wheat and other close-grown crops. In the Western portion, most conservation treatment needs are for wind erosion and for nitrogen loss in subsurface flows for irrigated acres.

Conservation treatment needs in the Missouri River Basin are proportionately lower than those in either the Upper Mississippi River Basin or in the Ohio-Tennessee River Basin because of lower precipitation, lower edge-of-field losses (other than wind erosion), and a higher level of conservation practice use. Only 1 percent of cropped acres in the Missouri River Basin have a **high** need for additional conservation treatment, compared to 15 percent for the Upper Mississippi River Basin and 24 percent for the Ohio-Tennessee River Basin. Only 17 percent of cropped acres in the Missouri River Basin have a **moderate** need for additional conservation treatment, compared to 45 percent for the Upper Mississippi River Basin and 46 percent for the Ohio-Tennessee River Basin.

Even though the percentage of cropped acres needing additional conservation treatment is lower in the Missouri River Basin than in the other two regions, the total number of under-treated acres is high. The 15.3 million cropped acres in the Missouri River Basin that have either a **high** or **moderate** need for additional conservation treatment is only slightly fewer than the 17.5 million under-treated acres in the Ohio-Tennessee River Basin.

Model simulations show that adoption of additional erosion control and nutrient management practices on the 15.3 million under-treated acres would, compared to the 2003–06 baseline, further reduce field losses in the region by—
- 37 percent for sediment loss due to water erosion,
- 24 percent for nitrogen lost with surface runoff,
- 12 percent for nitrogen loss in subsurface flows,
- 20 percent for phosphorus lost to surface water (sediment-attached and soluble), and
- 22 percent for wind erosion.

These field-level reductions would, in turn, further reduce loads delivered to rivers and streams from cultivated cropland. Relative to the 2003–06 baseline, this level of additional conservation treatment would reduce total ***instream loads*** *delivered from the region to the Mississippi River from all sources* by 1 percent for sediment, 6 percent for nitrogen, 4 percent for phosphorus, and 4 percent for atrazine. These reductions in instream loads from further conservation treatment are relatively modest because the bulk of the potential field-level savings from conservation treatment, relative to losses simulated for the no-practice scenario, have been achieved in this region.

Emerging technologies not evaluated in this study promise to provide additional conservation benefits once their use becomes more widespread. These include—
- Innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies and improved manure application equipment;
- Enhanced-efficiency nutrient application products such as slow or controlled release fertilizers, polymer coated products, nitrogen stabilizers, urease inhibitors, and nitrification inhibitors;
- Drainage water management that controls discharge of drainage water and treats contaminants, thereby reducing the levels of nitrogen loss and even some soluble phosphorus loss;
- Constructed wetlands receiving surface water runoff and drainage water from farm fields prior to discharge to streams and rivers; and
- Improved crop genetics that increase yields without increasing nutrient inputs.

Comprehensive Conservation Planning and Implementation Are Essential

The most pervasive conservation concern in the region is excessive rates of wind erosion during dry periods, including windborne losses of nitrogen and phosphorus. Wind erosion and windborne sediment adversely impact the soil, water, and air quality, and can cause human health issues.

Wind erosion accounts for most of the soil and nutrient losses from farm fields in this region. While conservation practices in use during 2003–06 have been effective in reducing wind erosion, model simulations show that rates can exceed 4 tons per acre in at least some years for 12 percent of the acres in the region, and exceed 2 tons per acre in some years for about 20 percent of the acres. About 60 percent of total phosphorus and 25 percent of total nitrogen lost from fields is with windborne sediment.

Wind erosion is much higher in the western portion of the basin, averaging 1.64 tons per acre per year. About 85 percent of total phosphorus and 35 percent of total nitrogen in the western portion of the basin are lost from farm fields with windborne sediment. Wind erosion in the eastern portion of the region averages 0.46 ton per acre, which is still high enough to be of concern in some years; 35 percent of total phosphorus and 15 percent of total nitrogen in this portion of the basin are lost from farm fields with windborne sediment.

Loss of sediment, nutrients, and pesticides with water is also important for some acres in the region. Most of the under-treated acres for resource concerns associated with water runoff are in the eastern portion of the basin. Most of the under-treated acres for nitrogen loss in subsurface flows are associated with irrigation water use in the western portion of the basin.

A ***comprehensive conservation planning process*** is required to identify the appropriate combination of soil erosion control practices and nutrient management techniques needed to simultaneously address soil erosion and nutrient and pesticide loss through the various loss pathways. A field with adequate conservation practice use will have a suite of practices that addresses all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses through the dominant loss pathways.

Targeting Enhances Effectiveness and Efficiency

Targeting program funding and technical assistance for accelerated treatment of acres with the most critical need for additional treatment is the most efficient way to reduce agricultural sources of contaminants from farm fields.

Not all acres provide the same benefit from conservation treatment. The more vulnerable acres, such as highly erodible land and soils prone to leaching, inherently lose more sediment or nutrients; therefore greater benefit can be attained with additional conservation treatment. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways. Most of the nutrients lost in subsurface flows return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

The least treated acres also provide greater benefits from treatment, especially if they are also inherently vulnerable to runoff, leaching, or wind erosion. The farmer survey showed that, while most acres benefit from use of conservation practices, environmentally “risky” management is still used on some acres (such as fall application of commercial fertilizers and manure for spring-planted crops, surface broadcast applications of commercial fertilizers and manure, and conventional tillage).

The practices in use in 2003–06 have already achieved 75 percent of potential reductions in sediment loss, 68 percent of potential reductions in nitrogen loss, and 76 percent of potential reductions in phosphorus loss. By treating all 15.3 million under-treated acres in the region with additional erosion control and nutrient management practices, an additional 10-percent reduction in potential sediment loss, an additional 11-percent reduction in potential nitrogen loss, and an additional 9 percent reduction in potential phosphorus loss could be achieved. To achieve 100 percent of potential savings (i.e., an additional 15 percent for sediment and phosphorus and 21 percent for nitrogen), additional conservation treatment for the 68.3 million low-treatment-need acres would be required.

Targeting is especially important in this region because of the low proportion of cropped acres that need additional treatment. Treating the 68.3 million acres that have a low need for additional treatment would provide very small per-acre reductions in field-level loss—an inefficient way to reduce loads delivered to rivers and streams. But significant per-acre reductions could be attained for the 15.3 million under-treated acres that do need additional treatment. Finding and treating these acres is an important challenge for program managers in this region.

Effects of Conservation Practices on Ecological Conditions Are Beyond the Scope of This Study

Ecological outcomes are not addressed in this report, nor were the estimates of conservation treatment needs specifically derived to attain Federal, State, or local water quality goals within the region.

Ecosystem impacts related to water quality are specific to each water body. Water quality goals also depend on the designated uses for each water body. In order to understand the effects of conservation practices on water quality in streams and lakes, it is first necessary to understand what is happening in the receiving waters and then evaluate whether the practices are having the desired effect on the current state of that aquatic ecosystem.

The regional scale of the design of this study precludes these kinds of assessments.

The primary focus of this report is on losses of potential pollutants from farm fields and prospects for attaining further loss reductions with additional soil erosion control and nutrient management practices. Conservation treatment needs were estimated to achieve "full treatment" from the field-level perspective, rather than to reduce instream loads to levels adequate for designated water uses. The simulated treatment levels were designed to minimally affect crop yields and maintain regional production capacity for food, fiber, forage, and fuel.

From this perspective, a field with adequate conservation treatment will have combinations of practices that address all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses. For purposes of this report, "full treatment" consists of a suite of practices that—

- *avoid* or limit the potential for contaminant losses by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- *control* overland flow where needed; and
- *trap* materials leaving the field using appropriate edge-of-field mitigation.

This field-based concept of "full conservation treatment" will likely be sufficient to protect water quality for some environmental settings. For more sensitive environmental settings, however, it may be necessary to adopt even stricter management criteria and techniques such as widespread use of cover crops, drainage water management, conservation rotations, or emerging production and conservation technologies. In some cases, attainment of water quality goals may even require watershed-scale solutions, such as sedimentation basins, wetland construction, streambank restoration, or an increased proportion of acres in long-term conserving cover.

Chapter 1
Land Use and Agriculture in the Missouri River Basin

Land Use

The Missouri River Basin covers about 510,000 square miles and includes parts of 10 states. The basin includes all of Nebraska and parts of Colorado, Iowa, Kansas, Minnesota, Missouri, Montana, North Dakota, South Dakota, and Wyoming. The basin extends from the continental divide and southern Canada through the northern Great Plains and discharges into the Mississippi River just north of St. Louis, Missouri.

The dominant land cover in the basin is rangeland (49 percent of the area), most of which is grass rangeland located in the western and central parts of the basin (table 1, fig. 1). Cultivated cropland accounts for about 29 percent of the area, the bulk of which is located in the eastern and southern parts of the basin. (Cultivated cropland includes land in long-term conserving cover, which is represented by acres enrolled in the General Sign-up of the Conservation Reserve Program [CRP].)

Forestland accounts for 9 percent of the area, most of which is located in the west and in central Missouri. Permanent pasture and hayland represent only 6 percent of the area, and water, wetlands, horticulture, and barren land account for about 4 percent of the area.The remaining 3 percent of the area consists of urban areas.

Table 1. Distribution of land cover in the Missouri River Basin

Land use	Acres*	Percent including water	Percent excluding water
Cultivated cropland and land enrolled in the CRP General Signup**	95,136,893	29	30
Hayland not in rotation with crops	9,119,126	3	3
Pastureland not in rotation with crops	9,560,505	3	3
Rangeland—grass	128,056,531	39	40
Rangeland—brush	33,880,130	10	11
Horticulture	49,292	<1	<1
Forestland			
Deciduous	9,644,807	3	3
Evergreen	19,000,573	6	6
Mixed	388,606	<1	<1
Urban	10,104,349	3	3
Wetlands			
Forested	3,049,744	1	1
Non-Forested	2,699,343	1	1
Barren	1,524,075	<1	<1
Subtotal	322,213,974	99	100
Water	4,351,630	1	--
Total	326,565,604	100	--

Source: 2001 National Land Cover Database for the Conterminous United States (Homer et al. 2007).
*Acreage estimates for cultivated cropland differ slightly from those based on the NRI-CEAP sample because of differences in data sources and estimation procedures. Acres enrolled in the CRP General Signup are used to represent land in long-term conserving cover.
**Includes hayland and pastureland in rotation with crops.

Major metropolitan areas center around Denver in Colorado and Kansas City in Kansas and Missouri. Urban land is also concentrated around Omaha, NE, and near the outlet of the Missouri River at St. Louis, MO.

Agriculture

The 2007 Census of Agriculture reported 267,832 farms in the Missouri River Basin, about 12 percent of the total number of farms in the United States (table 2). Land on farms was nearly 257 million acres, representing about 80 percent of the land base within the region. Farms in the Missouri River Basin make up about 28 percent of all land on farms in the nation. According to the 2007 Census of Agriculture, the value of Missouri River Basin agricultural sales in 2007 was about $49 billion—about 45 percent from crops and 55 percent from livestock.

About 57 percent of Missouri River Basin farms primarily raise crops, about 32 percent are primarily livestock operations, and the remaining 11 percent produce a mix of livestock and crops (table 3).

The average farm in this region is much larger than in most areas of the country—959 acres (table 2). Eleven percent of the farms have more than 2,000 acres and 21 percent have 500–2,000 acres (table 3). As in other regions, however, most of the farms are small in terms of gross sales; in 2007, 59 percent had less than $50,000 in total farm sales and 21 percent had $50,000–$250,000 in total farm sales (table 3). Farms with total agricultural sales greater than $250,000 (table 3) accounted for 20 percent of the farms in the region.

Crop production

The Missouri River Basin accounted for about 15 percent of all U.S. crop sales in 2007, totaling $22 billion (table 2). Corn, wheat, and soybeans are the principal crops grown. About one-fourth of the nation's corn and soybean acres and 40 percent of the nation's wheat acres are in this region. About 1 million acres of corn for silage and 16 million acres of hay, about half of which is alfalfa hay, are grown for use as livestock feed. Barley and sorghum for grain are also important crops in this region.

Irrigation is important for crop production in some parts of the region. About 13 million acres of harvested cropland were irrigated in 2007 (table 2), representing 16 percent of cropland harvested in the region and 26 percent of all irrigated harvested land in the nation.

Commercial fertilizers and pesticides are widely used on agricultural land in the region (table 2). In 2007, 62 million acres of cropland were fertilized, 60 million acres of cropland and pasture were treated with chemicals for weed control, and 15 million acres of hay and cropland were treated for insect control. About 3 million acres had manure applied in 2007.

Livestock operations

The Missouri River Basin accounted for about 17 percent of all U.S. livestock sales in 2007, totaling $27 billion (table 2). Livestock sales in the region are dominated by cattle sales,

which totaled $19.7 billion in 2007 and represented 32 percent of all cattle sales nationally (table 2). Hog and pig sales were also important, totaling $4.1 billion in sales in 2007 and representing 23 percent of the Nation's hog and pig sales.

In terms of animal units, livestock populations in the region are dominated by cattle, horses, sheep, and goats. An animal unit is 1,000 pounds of live animal weight calculated as a yearly average for each farm using information reported in the 2007 Census of Agriculture. Of the 23 million livestock animal units in the region, 15 million animal units are cattle, horses, sheep, and goats, excluding fattened cattle and dairy cows (table 2). Fattened cattle animal units total about 4.8 million, representing 37 percent of fattened cattle animal units in the nation. Swine animal units total 2.4 million, representing 24 percent of the swine animal units in the nation. Dairy cows, poultry, and other livestock make up only 5 percent of the livestock population in this region.

About 25,000 of the farms in the region (9 percent) could be defined as animal feeding operations (AFOs) (table 3). AFOs are livestock operations typically with confined poultry, swine, dairy cattle, or beef cattle. An additional 85,000 farms have significant numbers of pastured livestock (32 percent of farms). About 5,400 of the livestock operations (22 percent of the AFOs) are relatively large, with livestock numbers in 2007 above the EPA minimum threshold for a medium concentrated animal feeding operation (CAFO). Of these, about 2,100 meet livestock population criteria for a large CAFO.

Statistics for the Missouri River Basin reported in table 2 are for the year 2007 as reported in the Census of Agriculture. For some characteristics, different acre estimates are reported in subsequent sections based on the NRI-CEAP sample. Estimates based on the NRI-CEAP sample are for the time period 2003-2006. See chapter 2 for additional aspects of estimates based on the NRI-CEAP sample.

Watersheds

A hydrologic accounting system consisting of water resource regions, major subregions, and smaller watersheds has been defined by the U.S. Geological Survey (USGS) (1980). Each water resource region is designated with a 2-digit Hydrologic Unit Code (HUC), which is further divided into 4-digit subregions and then into 8-digit cataloging units, or watersheds. The Missouri River drainage is represented by 29 subregions.

The concentration of cultivated cropland within each subregion is an important indicator of the extent to which sediment and nutrient loads in rivers and streams are influenced by farming operations. Cultivated cropland makes up more than half of the land base in 10 of the 29 subregions (table 4 and fig. 2)—

- Missouri-Little Sioux River Basin (code 1023), with 78 percent,
- Missouri-Big Sioux-Lewis-Clark Lake (code 1017), with 67 percent,
- Missouri-Nishnabotna River Basin (code 1024), with 65 percent,
- Elkhorn River Basin (code 1022), with 59 percent,
- Republican River Basin (code 1025), with 56 percent,
- Missouri-Poplar River Basin (code 1006), with 56 percent,
- Middle and Lower Platte River Basin (code 1020), with 54 percent,
- James River Basin (code 1016), with 53 percent,
- Smoky Hill River Basin (code 1026), with 53 percent, and
- Kansas-Big Blue River Basin (code 1027), with 51 percent.

These 10 subregions have 56 percent of the cultivated cropland in the region. Cultivated cropland makes up 40 percent or less of the land base in each of the other subregions (table 4).

Cultivated cropland is a minor land use in six subregions, where it accounts for only a small percentage of the land base within each subregion—

- Powder-Tongue River Basin (code 1009), with 1 percent,
- Big Horn River Basin (code 1008), with 3 percent,
- Missouri Headwaters (code 1002), with 3 percent,
- Missouri-Grand-Moreau-Lake Oahe (code 1012), with 4 percent,
- Upper Yellowstone River Basin (code 1007), with 7 percent, and
- North Platte River Basin (code 1018), with 8 percent.

Cultivated cropland includes land in long-term conserving cover, which represents about 12 percent of the cultivated cropland acres in this region (table 4). Subregions where land in long-term conserving cover is 20 percent or more of cultivated cropland acres are—

- Chariton-Grand River Basin (code 1028), with 33 percent,
- Powder-Tongue River Basin (code 1009), with 25 percent,
- Missouri-Poplar River Basin (code 1006), with 21 percent,
- Missouri-Musselshell-Fort Peck Lake (code 1004), with 21 percent, and
- Cheyenne River (code 1013), with 20 percent.

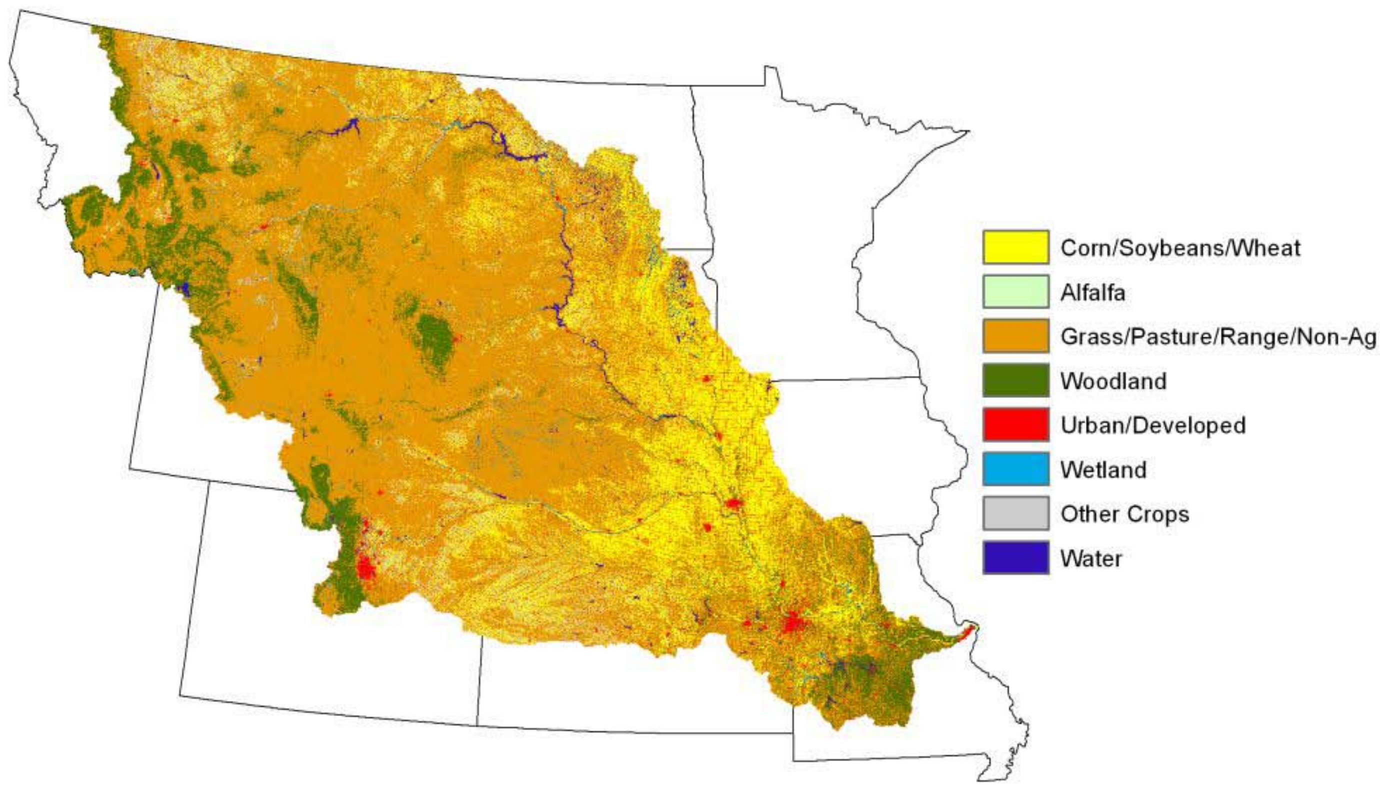
Table 2. Profile of farms and land in farms in the Missouri River Basin, 2007

Characteristic	Value	Percent of national total
Number of farms	267,832	12
Acres on farms	256,892,881	28
Average acres per farm	959	
Cropland harvested, acres	81,388,773	26
Cropland used for pasture, acres	7,139,131	20
Cropland on which all crops failed, acres	1,813,275	24
Cropland in summer fallow, acres	8,168,529	52
Cropland idle or used for cover crops, acres	12,032,518	32
Woodland pastured, acres	3,547,009	12
Woodland not pastured, acres	2,309,033	5
Permanent pasture and rangeland, acres	134,080,604	33
Other land on farms, acres	6,414,009	20
Principal crops grown		
Field corn for grain harvested, acres	23,135,820	27
Wheat harvested, all types, acres	20,570,339	40
Soybeans harvested, acres	15,071,210	24
Alfalfa hay harvested, acres	7,584,649	37
Tame and wild hay harvested, acres	7,253,619	21
Sorghum for grain harvested, acres	1,633,120	24
Barley harvested, acres	1,304,720	37
Field corn for silage harvested, acres	1,082,849	18
Small grain hay harvested, acres	1,011,459	26
Irrigated harvested land, acres	13,215,761	26
Irrigated pastureland or rangeland, acres	942,595	19
Cropland fertilized, acres	62,341,505	26
Pastureland fertilized, acres	4,593,161	18
Land treated for insects on hay or other crops, acres	14,693,323	16
Land treated for nematodes in crops, acres	689,901	9
Land treated for diseases in crops and orchards, acres	3,788,043	17
Land treated for weeds in crops and pasture, acres	60,017,729	27
Crops on which chemicals for defoliation applied, acres	239,647	2
Acres on which manure was applied	3,045,583	14
Total grains and oilseeds sales, million dollars	20,190	26
Total hay and other crop sales, million dollars	1,055	11
Total nursery, greenhouse, and floriculture sales, million dollars	459	3
Total vegetable, melons sales, million dollars	242	2
Total crop sales, million dollars	21,966	15
Total dairy sales, million dollars	1,476	5
Total hog and pigs sales, million dollars	4,098	23
Total poultry and eggs sales, million dollars	1,087	3
Total cattle sales, million dollars	19,720	32
Total sheep, goats, and their products sales, million dollars	193	27
Total horses, ponies, and mules sales, million dollars	84	4
Total other livestock sales, million dollars	152	6
Total livestock sales, million dollars	26,810	17
Animal units on farms		
All livestock types	22,999,761	22
Swine	2,415,041	24
Dairy cows	621,242	5
Fattened cattle	4,846,621	37
Other cattle, horses, sheep, goats	14,597,324	25
Chickens, turkeys, and ducks	377,053	5
Other livestock	142,480	35

Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA

Note: Information in the Census of Agriculture was used to estimate animal units using methods and assumptions described in USDA/NRCS (2003).

Figure 1. Land cover in the Missouri River Basin



Source: National Agricultural Statistics Service (NASS 2007).

Table 3. Characteristics of farms in the Missouri River Basin, 2007

	Number of farms	Percent of farms in Missouri River Basin
Farming primary occupation	136,994	51
Farm size:		
<50 acres	59,445	22
50–500 acres	123,118	46
500–2,000 acres	56,934	21
>2,000 acres	28,335	11
Farm sales:		
<$10,000	110,936	41
$10,000–50,000	48,659	18
$50,000–250,000	55,936	21
$250,000–500,000	23,289	9
>$500,000	29,012	11
Farm type:		
Crop sales make up more than 75 percent of farm sales	151,483	57
Livestock sales make up more than 75 percent of farm sales	86,622	32
Mixed crop and livestock sales	29,727	11
Farms with no livestock sales	106,100	40
Farms with few livestock or specialty livestock types	51,594	19
Farms with pastured livestock and few other livestock types	85,480	32
Farms with animal feeding operations (AFOs)*	24,658	9

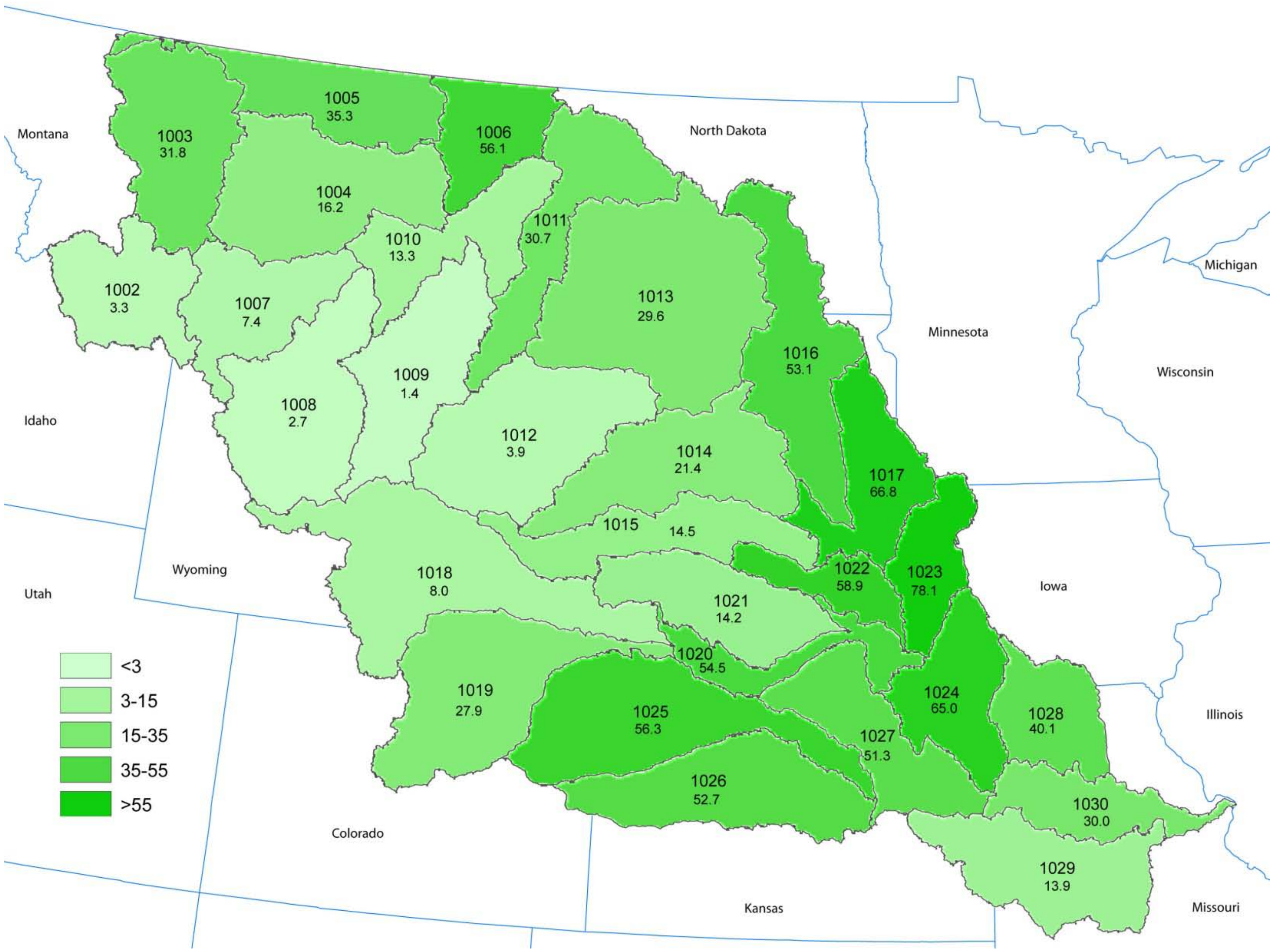
Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA
* AFOs, as defined here, typically have a total of more than 12 animal units consisting of fattened cattle, dairy cows, hogs and pigs, chickens, ducks, and turkeys.

Table 4. Cultivated cropland use in the 29 subregions in the Missouri River Basin*

Subregion	Total area (acres)	Cultivated cropland (acres)**	Percent cultivated cropland in subregion	Percent of cultivated cropland in Missouri River Basin	Percent of cultivated cropland acres in long-term conserving cover
Missouri Headwaters (code 1002)	8,976,755	294,774	3.3	0.3	7.2
Upper Missouri-Marias (code 1003)	12,716,515	4,038,470	31.8	4.2	9.6
Missouri-Musselshell-Fort Peck Lake (code 1004)	15,016,113	2,434,596	16.2	2.6	21.0
Milk River Basin (code 1005)	9,602,813	3,394,217	35.3	3.6	17.5
Missouri-Poplar River Basin (code 1006)	6,846,793	3,843,637	56.1	4.0	21.3
Upper Yellowstone River Basin (code 1007)	9,238,608	683,901	7.4	0.7	11.6
Big Horn River Basin (code 1008)	14,664,617	395,118	2.7	0.4	3.2
Powder-Tongue River Basin (code 1009)	12,041,131	168,463	1.4	0.2	24.8
Lower Yellowstone River (code 1010)	8,914,365	1,187,451	13.3	1.2	16.7
Missouri-Little Missouri-Lake Sakakawea (code 1011)	10,919,501	3,349,305	30.7	3.5	14.5
Missouri-Grand-Moreau-Lake Oahe (code 1012)	15,520,741	600,982	3.9	0.6	9.6
Cheyenne River (code 1013)	23,735,141	7,034,158	29.6	7.4	19.7
Missouri-White River -Fort Randall Reservoir (code 1014)	12,986,614	2,777,598	21.4	2.9	15.1
Niobrara River Basin (code 1015)	9,008,209	1,301,916	14.5	1.4	13.5
James River Basin (code 1016)	13,701,319	7,274,251	53.1	7.6	12.5
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	9,082,415	6,063,109	66.8	6.4	5.2
North Platte River Basin (code 1018)	19,929,247	1,587,299	8.0	1.7	15.0
South Platte River Basin (code 1019)	15,460,346	4,306,970	27.9	4.5	12.1
Middle and Lower Platte River Basin (code 1020)	5,268,508	2,871,335	54.5	3.0	2.5
Loup River Basin (code 1021)	9,694,845	1,374,243	14.2	1.4	6.0
Elkhorn River Basin (code 1022)	4,491,238	2,643,130	58.9	2.8	5.8
Missouri-Little Sioux River Basin (code 1023)	5,985,882	4,675,112	78.1	4.9	4.4
Missouri-Nishnabotna River Basin (code 1024)	8,692,040	5,646,766	65.0	5.9	8.0
Republican River Basin (code 1025)	15,972,335	8,990,231	56.3	9.4	8.4
Smoky Hill River Basin (code 1026)	12,790,717	6,743,897	52.7	7.1	9.8
Kansas-Big Blue River Basin (code 1027)	9,716,566	4,985,834	51.3	5.2	4.9
Chariton-Grand River Basin (code 1028)	7,013,318	2,811,282	40.1	3.0	33.2
Gasconade-Osage River Basin (code 1029)	11,932,265	1,661,763	13.9	1.7	15.3
Lower Missouri-Lower Missouri-Blackwater (code 1030)	6,646,646	1,997,085	30.0	2.1	8.6
Total*	326,565,604	95,136,893	29.1	100.0	11.7

Source: 2001 National Land Cover Database for the Conterminous United States (Homer et al. 2007) and the 1997 National Resources Inventory (USDA/NRCS 2002).
* Excludes subregion 1001, which flows north to the Saskatchewan River in Canada.
** Acres of cultivated cropland include land in long-term conserving cover. Estimates of cultivated cropland were obtained from HUMUS databases on land use, differing slightly from acreage estimates obtained with the NRI-CEAP sample.

Figure 2. Percent cultivated cropland, including land in long-term conserving cover, for the 29 subregions in the Missouri River Basin



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Chapter 2
Overview of Sampling and Modeling Approach

Scope of Study

This study was designed to evaluate the effects of conservation practices at the regional scale to provide a better understanding of how conservation practices are benefiting the environment and to determine what challenges remain. The report does the following.

- Evaluates the extent of conservation practice use in the region in 2003–06;
- Estimates the environmental benefits and effects of conservation practices in use;
- Estimates conservation treatment needs for the region; and
- Estimates potential gains that could be attained with additional conservation treatment.

The study was designed to quantify the effects of commonly used conservation practices on cultivated cropland, regardless of how or why the practices came to be in use. This assessment is not an evaluation of Federal conservation programs, because it is not restricted to only those practices associated with Federal conservation programs.

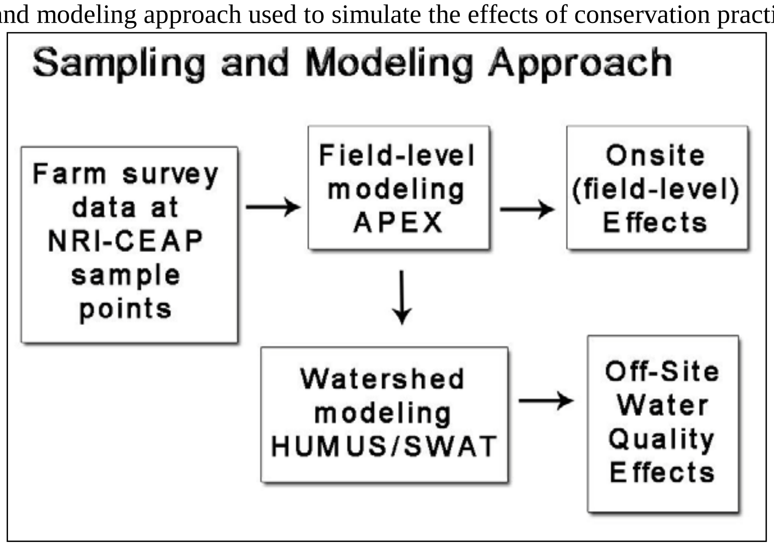
For purposes of this report, cultivated cropland includes land in row crops or close-grown crops (such as wheat and other small grain crops), hay and pasture in rotation with row crops and close-grown crops, and land in long-term conserving cover. Cultivated cropland does not include agricultural land that has been in hay, pasture, or horticulture for 4 or more consecutive years. Acres enrolled in the General Signup of the Conservation Reserve Program (CRP) were used to represent cultivated cropland currently in long-term conserving cover.

Sampling and Modeling Approach

The assessment uses a statistical sampling and modeling approach to estimate the environmental effects and benefits of conservation practices (fig. 3).

- A subset of 3,916 National Resources Inventory (NRI) sample points provides a statistical sample that represents the diversity of soils and other conditions for cropped acres in the Missouri River Basin. The sample also includes 4,281 additional NRI sample points designated as CRP acres to represent 11.2 million acres of land in long-term conserving cover. NRI sample points are linked to NRCS Soil Survey databases and were linked spatially to climate databases for this study.
- A farmer survey—the NRI-CEAP Cropland Survey—was conducted at each of the 3,916 cropped sample points during the period 2003–06 to determine what conservation practices were in use and to collect information on farming practices.
- The field-level effects of the conservation practices were assessed using a field-scale physical process model—the Agricultural Policy Environmental Extender (APEX)—which simulates the day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of soil, nutrients, and pesticides.
- A watershed model and system of databases—the Hydrologic Unit Model for the United States (HUMUS)—was used to simulate how reductions of field losses have reduced instream concentrations and loadings of sediment, nutrients, and pesticides within the Missouri River Basin. The SWAT model (Soil and Water Assessment Tool) was used to simulate nonpoint source loadings from land uses other than cropland and to route instream loads from one watershed to another.

Figure 3. Statistical sampling and modeling approach used to simulate the effects of conservation practices



The modeling strategy for estimating the effects of conservation practices consists of two model scenarios that are produced for each sample point.

3. A baseline scenario, the "baseline conservation condition" scenario, provides model simulations that account for cropping patterns, farming activities, and conservation practices as reported in the NRI-CEAP Cropland Survey and other sources.
4. An alternative scenario, the "no-practice" scenario, simulates model results as if no conservation practices were in use but holds all other model inputs and parameters the same as in the baseline conservation condition scenario.

The effects of conservation practices are obtained by taking the difference in model results between the two scenarios (fig. 4) [1] For example, to simulate "no practices" for sample points where some type of residue management is used, model simulations were conducted as if continuous conventional tillage had been used. Similarly, for sample points with structural conservation practices (buffers, terraces, grassed waterways, etc.), the no-practice scenario was simulated as if the practices were not present. The no-practice representation for land in long-term conserving cover was derived from model results for cropped acres as simulated in the no-practice scenario, representing how the land would have been managed had crops been grown without the use of conservation practices.

The approach captures the diversity of land use, soils, climate, and topography from the NRI; accounts for site-specific farming activities; estimates the loss of materials at the field scale where the science is most developed; and provides a statistical basis for aggregating results to the national and regional levels. Previous studies have used this NRI micro-simulation modeling approach to estimate soil loss, nutrient loss, and change in soil organic carbon (Potter et al. 2006), to estimate pesticide loss from cropland (Kellogg et al. 1992, 1994, 2002; Goss et al. 1998), and to identify priority watersheds for water quality protection from nonpoint sources related to agriculture (Kellogg 2000, Kellogg et al. 1997, Goebel and Kellogg 2002).

The NRI and the CEAP Sample

The approach is an extension of the NRI, a longitudinal, scientifically based survey designed to gauge natural resource status, conditions, and trends on the Nation's non-Federal land (Goebel 1998; USDA/NRCS 2002).

The NRI sampling design implemented in 1982 provided a stratified, two-stage, unequal probability area sample of the entire country (Goebel and Baker 1987; Nusser and Goebel 1997). Nominally square areas/segments were selected within geographical strata on a county-by-county basis; specific point locations were selected within each selected segment. The segments ranged in size from 40 to 640 acres but were typically half-mile square areas, and most segments contained three sample points.

At each sample point, information is collected on nearly 200 attributes; some items are also collected for the entire segment. The sampling rates for the segments were variable, typically from 2 to 6 percent in agricultural strata and much lower in remote nonagricultural areas. The 1997 NRI Foundation Sample contained about 300,000 sample segments and about 800,000 sample points.

Figure 4. Modeling strategy used to assess effects of conservation practices

[1] This modeling strategy is analogous to how the NRI produces estimates of soil erosion and the intrinsic erosion rate used to identify highly erodible land. The NRI uses the Universal Soil Loss Equation (USLE) to estimate sheet and rill erosion at each sample point on the basis of site-specific factors. Soil loss per unit area is equal to R*K*L*S*C*P. The first four factors—R, K, L, S—represent the conditions of climate, soil, and topography existing at a site. (USDA 1989). The last two factors—C and P—represent the degree to which management influences the erosion rate. The product of the first four factors is sometimes called the intrinsic, or potential, erosion rate. The intrinsic erosion rate divided by T, the soil loss tolerance factor, produces estimates of EI, the erodibility index. The intrinsic erosion rate is thus a representation of a "no-practice" scenario where C=1 represents smooth-tilled continuous fallow and P=1 represents no supporting practices.

NRCS made several significant changes to the NRI program over the past 10 years, including transitioning from a 5-year periodic survey to an annual survey. The NRI's annual design is a *supplemented panel design.* [2] A *core panel* of 41,000 segments is sampled each year, and *rotation (supplemental) panels* of 31,000 segments each vary by inventory year and allow an inventory to focus on an emerging issue. The core panel and the various supplemental panels are unequal probability subsamples from the 1997 NRI Foundation Sample.

The CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA/NRCS 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample.[3] The sample is statistically representative of cultivated cropland and formerly cultivated land currently in long-term conserving cover.

Nationally, there were over 30,000 samples in the original sample draw. A completed farmer survey was required to include the sample point in the CEAP sample. Some farmers declined to participate in the survey, others could not be located during the time period scheduled for implementing the survey, and other sample points were excluded for administrative reasons such as overlap with other USDA surveys. Some sample points were excluded because the surveys were incomplete or contained inconsistent information, land use found at the sample point had recently changed and was no longer cultivated cropland, or the crops grown were uncommon and model parameters for crop growth were not available. The national NRI-CEAP usable sample consists of about 18,700 NRI points representing cropped acres, and about 13,000 NRI points representing land enrolled in the General Signup of the CRP.

The NRI-CEAP Cropland Survey

A farmer survey—the NRI-CEAP Cropland Survey—was conducted to obtain the additional information needed for modeling the 3,916 sample points with crops.[4] The USDA National Agricultural Statistics Service (NASS) administered the survey. Farmer participation was voluntary, and the information gathered is confidential. The survey content was specifically designed to provide information on farming activities for use with a physical process model to estimate field-level effects of conservation practices.

The survey obtained information on—

- crops grown for the previous 3 years, including double crops and cover crops;
- field characteristics, such as proximity to a water body or wetland and presence of tile or surface drainage systems;
- conservation practices associated with the field;
- crop rotation plan;
- application of commercial fertilizers (rate, timing, method, and form) for crops grown the previous 3 years;
- application of manure (source and type, consistency, application rate, method, and timing) on the field over the previous 3 years;
- application of pesticides (chemical, rate, timing, and method) for the previous 3 years;
- pest management practices;
- irrigation practices (system type, amount, and frequency);
- timing and equipment used for all field operations (tillage, planting, cultivation, harvesting) over the previous 3 years, and;
- general characteristics of the operator and the operation.

In a separate data collection effort, NRCS field offices provided information on the practices specified in conservation plans for the CEAP sample points.

Because of the large size of the sample, it was necessary to spread the data collection process over a 4-year period, from 2003 through 2006. In each year, surveys were obtained for a separate set of sample points. The final CEAP sample was constructed by pooling the set of usable, completed surveys from all 4 years.

Simulating the Effects of Weather

Weather is the predominant factor determining the loss of soil, nitrogen, phosphorus, and pesticides from farm fields, and has a big influence on the effectiveness of conservation practices. To capture the effects of weather, each scenario was simulated using 47 years of actual daily weather data for the time period 1960 through 2006. The 47-year record is a serially complete daily data set of weather station data from weather station records available from the NCDC (National Climatic Data Center) for the period 1960 to 2006, including precipitation, temperature maximum, and temperature minimum (Eischeid et al. 2000). These data were combined with the respective PRISM (Parameter–Elevation Regressions on Independent Slopes Model; Daly et al. 1994) monthly map estimates to construct daily estimates of precipitation and temperature (Di Luzio et al. 2008). The same 47-year weather data were used in the HUMUS/SWAT simulations and in the APEX model simulations.

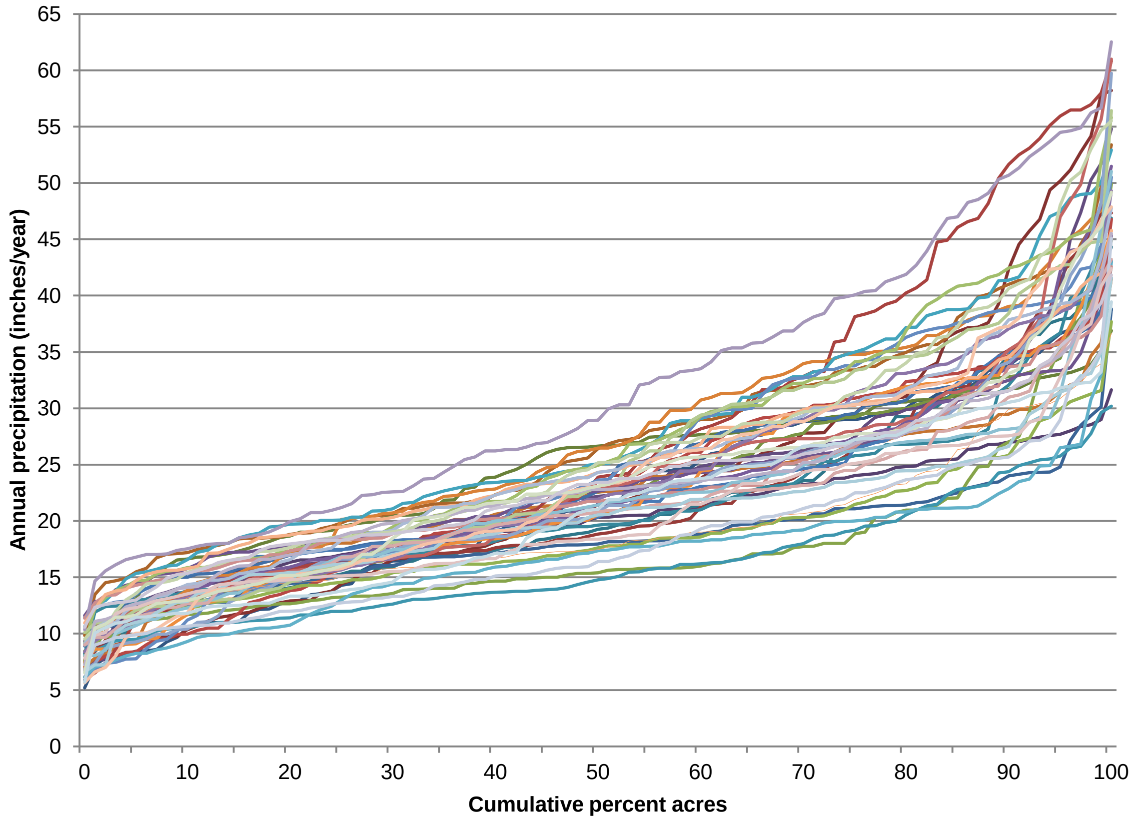
Annual precipitation over the 47-year simulation averaged about 23 inches for cropped acres in this region. However, annual precipitation varied substantially in the model simulations, both within the region and from year to year, as shown in figure 5. Each curve in figure 5 shows how annual precipitation varied over the region in one of the 47 years. The family of curves shows the variability from year to year. In general, annual precipitation ranges from lows of 5–10 inches per year to highs of 30-60 inches per year. The top curve shown is for the year 1993, the wettest year in this region during the 47 years. The curve for 1993 shows that precipitation exceeded the long-term annual average of 23 inches for 70 percent of the cropped acres in the Missouri River Basin. The bottom curves are drought years for most of the region—1966, 1974, 1976, and 1988—when 85 percent of the cropped acres had less precipitation than the long-term annual average.

[2] For more information on the NRI sample design, see www.nrcs.usda.gov/technical/NRI/.
[3] Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap.
[4] The surveys, the enumerator instructions, and other documentation can be found at www.nrcs.usda.gov/technical/nri/ceap.

The western portion of the basin gets less precipitation than the eastern portion of the basin. To show this, the region was split into two parts for this study, as shown in figure 6, and annual precipitation contrasted in figures 7 and 8. Annual precipitation over the 47-year simulation averaged about 29 inches for cropped acres in the eastern portion and about 18 inches for cropped acres in the western portion. Year-to-year variability was also more pronounced in the eastern portion.

Throughout most of this report model results are presented in terms of the 47-year averages where weather is the only input variable that changes year to year. Since we used the cropping patterns and practices for the 2003–06 period, we did not simulate *actual* loses for each of these years. Rather, we provide estimates of what model outputs would *average* over the long-term if weather varied as it has over the past 47 years. Similarly, estimates of the average effects of conservation practices include effectiveness in extreme weather years, such as floods and prolonged droughts, as represented in the 47-year weather record shown in figures 5, 7, and 8.

Figure 5. Cumulative distributions of annual precipitation used in the model simulations for cropped acres in the Missouri River Basin



Note:. Each of the 47 curves shown above represents a single year of data and shows how annual precipitation varies over the region in that year, starting with the acres with the lowest precipitation within the region and increasing to the acres with the highest precipitation. The family of curves shows how annual precipitation varies from year to year. Annual precipitation over the 47-year simulation averaged about 23 inches for cropped acres throughout the region.

Figure 6. Split between the eastern portion (green) and the western portion (brown) for the Missouri River Basin*

* The Middle and Lower Platte River Basin (code 1020) is split between the eastern and western regions; the 6-digit HUC 102001 is included in the western portion and the 6-digit HUC 102002 is included in the eastern portion.

Figure 7. Mean, minimum, and maximum levels of annual precipitation used in the model simulations for cropped acres in the ***eastern portion*** of the Missouri River Basin

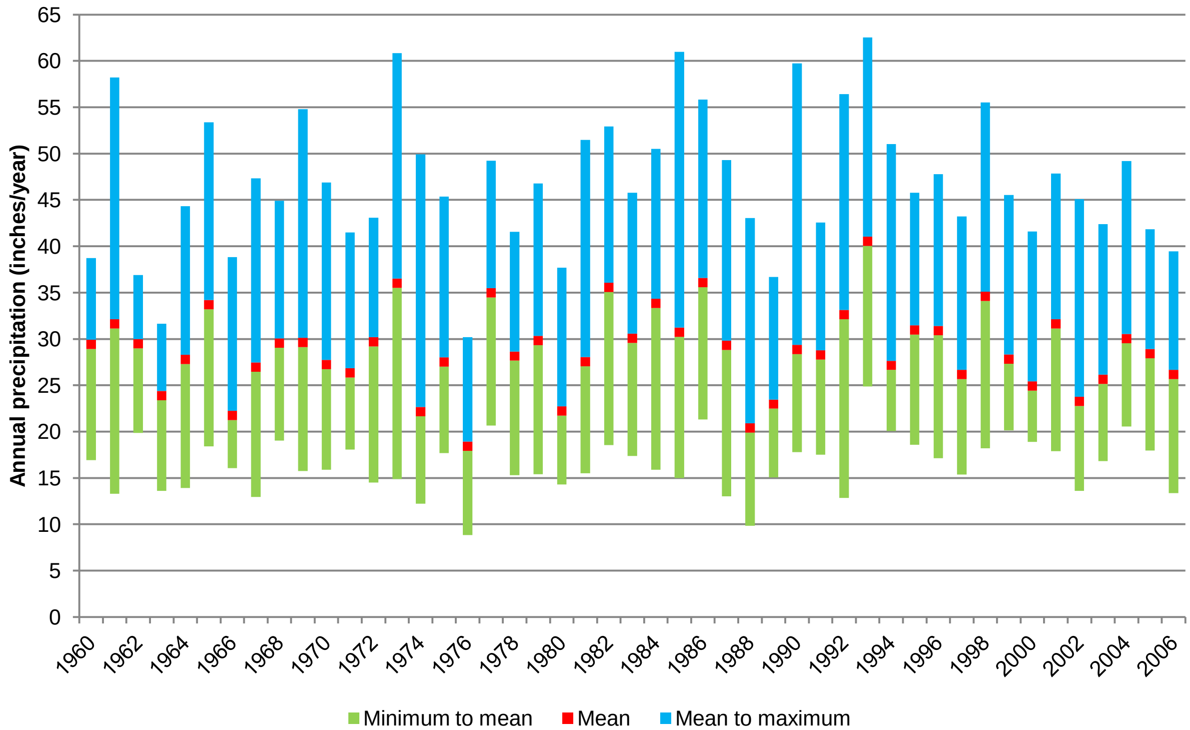
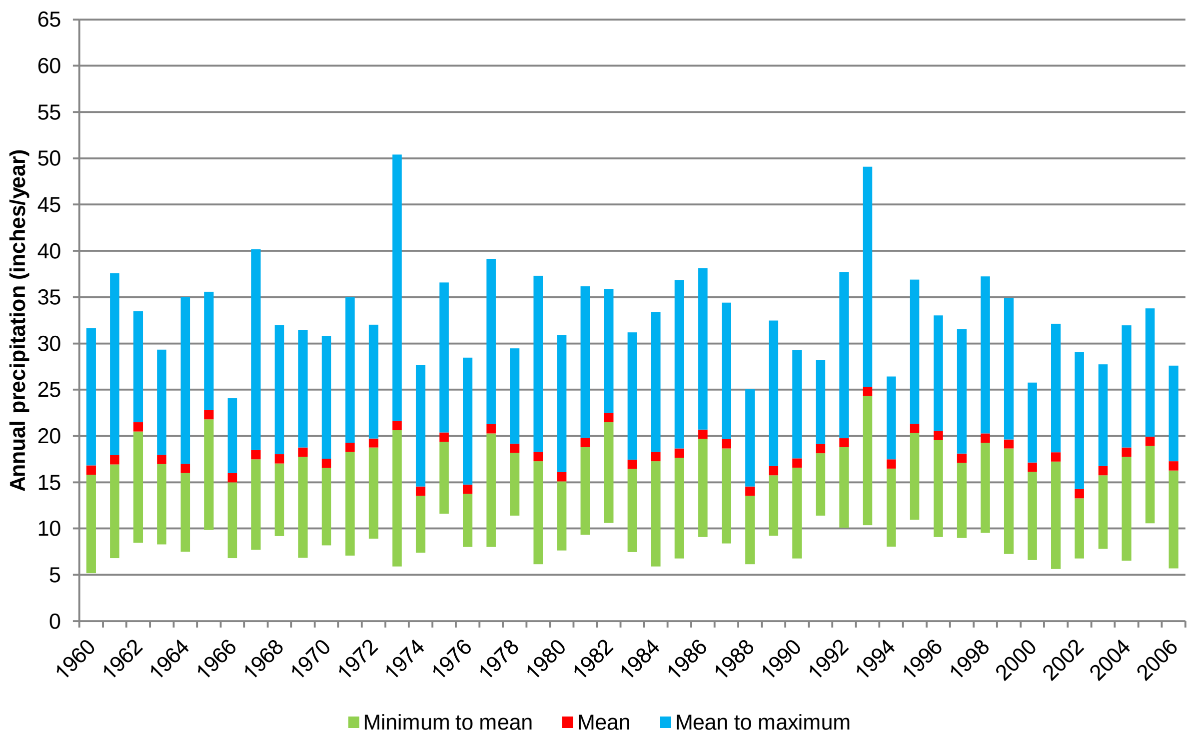


Figure 8. Mean, minimum, and maximum levels of annual precipitation used in the model simulations for cropped acres in the ***western portion*** of the Missouri River Basin



Estimated Acres

Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with the statistical sample. For example, the 95-percent confidence interval for the estimate of 83,614,500 cropped acres in the region has a lower bound of 81,704,869 acres and an upper bound of 85,524,131 acres. (The lower bound is the estimate minus the margin of error and the upper bound is the estimate plus the margin of error.)

The CEAP sample was designed to allow reporting of results at the subregion (4-digit HUC) level in most cases. The acreage weights were derived so as to approximate total cropped acres by subregion as estimated by the full 2003 NRI. The sample size is too small, in most cases, for reliable and defensible reporting of results for areas below the subregion level. In the Missouri River Basin, sample sizes for three subregions were too small to reliably report cropped acres. These three subregions were combined with neighboring subregions for reporting of results by subregion:

- The Missouri Headwaters subregion (code 1002), with only 8 sample points, was combined with the Upper Missouri-Marias Rivers subregion (code1003).
- The Powder-Tongue Rivers subregion (code 1009), with only 6 sample points, was combined with the Big Horn River subregion (code 1008).
- The Cheyenne River subregion (code 1012), with only 11 sample points, was combined with the Missouri-Grand-Moreau-Lake Oahe subregion (code 1013).

NRI-CEAP estimates of cropped acres for the 29 subregions within the Missouri River Basin are presented in table 5 along with the 95-percent confidence intervals. These estimates of cropped acres differ from cultivated cropland estimates presented in tables 1 and 4 primarily because those tables also include 11.2 million acres of land in long-term conserving cover but also because of differences in data sources and estimation procedures. Margins of error for a selection of other estimated cropped acres used in this report are presented in appendix A.

Table 5. Estimated cropped acres based on the NRI-CEAP sample for subregions in the Missouri River Basin

Subregion	Number of CEAP samples	Estimated acres (1,000 acres)	95-percent confidence interval: Lower bound (1,000 acres)	95-percent confidence interval: Upper bound (1,000 acres)
Western portion of the region				
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	93	3,714	2,937	4,491
Missouri-Musselshell-Fort Peck Lake (code 1004)	48	1,235	777	1,693
Milk River Basin (code 1005)	51	2,027	1,432	2,621
Missouri-Poplar River Basin (code 1006)	114	2,595	2,136	3,054
Upper Yellowstone River Basin (code 1007)	30	453	178	728
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	37	625	421	828
Lower Yellowstone River (code 1010)	43	877	571	1,183
Missouri-Little Missouri-Lake Sakakawea (code 1011)	93	2,678	2,343	3,014
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	202	7,066	6,301	7,830
Missouri-White River -Fort Randall Reservoir (code 1014)	109	2,653	2,302	3,003
Niobrara River Basin (code 1015)	46	1,155	979	1,332
North Platte River Basin (code 1018)	44	986	726	1,246
South Platte River Basin (code 1019)	154	3,304	2,920	3,689
Loup River Basin (code 1021)	65	1,498	1,140	1,855
Republican River Basin (code 1025)	330	7,891	7,242	8,540
Smoky Hill River Basin (code 1026)	162	7,146	6,443	7,850
Middle and Lower Platte River Basin (code 102001)*	68	1,354	1,115	1,593
Subtotal	1,689	47,257	45,713	48,800
Eastern portion of the region				
Middle and Lower Platte River Basin (code 102002)*	75	1,174	949	1,400
James River Basin (code 1016)	267	7,124	6,480	7,769
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	414	5,685	5,296	6,074
Elkhorn River Basin (code 1022)	103	2,338	2,077	2,599
Missouri-Little Sioux River Basin (code 1023)	230	4,541	3,975	5,107
Missouri-Nishnabotna River Basin (code 1024)	380	5,208	4,626	5,789
Kansas-Big Blue River Basin (code 1027)	335	4,870	4,416	5,323
Chariton-Grand River Basin (code 1028)	157	2,058	1,793	2,324
Gasconade-Osage River Basin (code 1029)	107	1,502	1,199	1,805
Lower Missouri-Lower Missouri-Blackwater (code 1030)	159	1,858	1,674	2,041
Subtotal	2,227	36,358	34,932	37,784
Total	3,916	83,614	81,705	85,524

* The Middle and Lower Platte River Basin (code 1020) is split between the eastern and western regions; the 6-digit HUC 102001 is included in the western portion and the 6-digit HUC 102002 is included in the eastern portion.
Note: Estimates are from the NRI-CEAP Cropland Survey.

Cropping Systems in the Missouri River Basin

Cropping systems were defined on the basis of the crops grown at CEAP sample points over the 3 years that information was obtained on farming activities at each sample point. Statistical sample weights for each sample point were derived from the NRI crop history at each sample point so as to approximate acres reported in the 2003 NRI for similar cropping systems at the 4-digit HUC level. (Cropping system acres were only one of several factors taken into account in deriving the acreage weights for each sample point.)

Predominant cropping systems in the eastern portion of the region are markedly different from those in the western portion of the region. Table 6 provides a breakdown of sample sizes and estimated cropped acres in the Missouri River Basin by cropping system, with separate estimates for the eastern and western portions of the basin. For the region as a whole, corn-soybean rotations without other crops and “wheat only” systems dominated crops grown in the Missouri River Basin, representing 32 percent and 23 percent of cropped acres, respectively. However, of the 27.1 million acres of “corn-soybean only” acres in the region, all but 2.8 million are in the eastern portion of the region. Of the 19.5 million acres of “wheat only,” 19.3 million are in the western portion of the region.

Other cropping systems mostly found in the eastern portion of the region include cropping systems with soybeans:

- Corn-soybean with close grown crops,
- Soybean only, and
- Soybean-wheat only.

The “corn only” cropping system is proportionately about the same in both regions, representing 5 percent of the cropped acres in the eastern portion and 7 percent of cropped acres in the western portion.

Most of the other cropping systems are predominantly found in the western portion of the region.

Table 6. Estimated crop acres for cropping systems in the Missouri River Basin

	Eastern portion of region			Western portion of region			Entire region		
	Number of CEAP samples	Estimated acres (1,000 acres)	Percent of total	Number of CEAP samples	Estimated acres (1,000 acres)	Percent of total	Number of CEAP samples	Estimated acres (1,000 acres)	Percent of total
Corn-soybean only	1,528	24,233	67	129	2,824	6	1,657	27,057	32
Corn only	105	1,766	5	155	3,135	7	260	4,901	6
Corn-soybean with close grown crops	125	1,955	5	22	487	1	147	2,441	3
Corn and close grown crops	45	808	2	127	3,516	7	172	4,324	5
Soybean only	94	1,413	4	5	<200	<1	99	1,521	2
Soybean-wheat only	111	2,026	6	23	645	1	134	2,671	3
Wheat only	12	244	<1	629	19,287	41	641	19,532	23
Sorghum-wheat and sorghum only	17	328	<1	78	2,846	6	95	3,174	4
Sunflower and close grown crops	9	<200	<1	60	1,782	4	69	1,979	2
Vegetables with and without other crops	10	313	<1	69	1,657	4	79	1,969	2
Hay-crop mix	63	1,058	3	119	3,522	7	182	4,580	5
Remaining mix of row and close-grown crops	48	1,113	3	198	5,214	11	246	6,327	8
Remaining mix of row crops	58	882	2	30	551	1	88	1,432	2
Remaining mix of close-grown crops	2	<200	<1	45	1,683	4	47	1,706	2
Total	2,227	36,358	100	1,689	47,257	100	3,916	83,614	100

Chapter 3
Evaluation of Conservation Practice Use—the Baseline Conservation Condition

This study assesses the use and effectiveness of conservation practices in the Missouri River Basin for the period 2003 to 2006 to determine the baseline conservation condition for the region. The baseline conservation condition provides a benchmark for estimating the effects of existing conservation practices as well as projecting the likely effects of alternative conservation treatment. Conservation practices that were evaluated include structural practices, annual practices, and long-term conserving cover.

Structural conservation practices, once implemented, are usually kept in place for several years. Designed primarily for erosion control, they also mitigate edge-of-field nutrient and pesticide loss. Structural practices evaluated include—

- in-field practices for water erosion control, divided into two groups:
  - practices that control overland flow (terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping), and
  - practices that control concentrated flow (grassed waterways, grade stabilization structures, diversions, and other structures for water control);
- edge-of-field practices for buffering and filtering surface runoff before it leaves the field (riparian forest buffers, riparian herbaceous cover, filter strips, field borders); and
- wind erosion control practices (windbreaks/shelterbelts, cross wind trap strips, herbaceous wind barriers, hedgerow planting).

Annual conservation practices are management practices conducted as part of the crop production system each year. These practices are designed primarily to promote soil quality, reduce in-field erosion, and reduce the availability of sediment, nutrients, and pesticides for transport by wind or water. They include—

- residue and tillage management;
- nutrient management practices;
- pesticide management practices; and
- cover crops.

Long-term conservation cover establishment consists of planting suitable native or domestic grasses, forbs, or trees on environmentally sensitive cultivated cropland.

Historical Context for Conservation Practice Use

The use of conservation practices in the Missouri River Basin closely reflects the history of Federal conservation programs and technical assistance. In the beginning the focus was almost entirely on reducing soil erosion and preserving the soil's productive capacity. In the 1930s and 1940s, Hugh Hammond Bennett, the founder and first chief of the Soil Conservation Service (now Natural Resources Conservation Service) instilled in the national ethic the need to treat every acre to its potential by controlling soil erosion and water runoff. Land shaping structural practices (such as terraces, contour farming, and stripcropping) and sediment control structures were widely adopted. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. Conservation tillage, along with use of crop rotations and cover crops, was used either alone or in combination with structural practices. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres, tying farm commodity payments to conservation treatment of highly erodible land. The Conservation Reserve Program was established to enroll the most erodible cropland acres in multi-year contracts to plant acres in long-term conserving cover.

During the 1990s, the focus of conservation efforts began to shift from soil conservation and sustainability to reducing pollution impacts associated with agricultural production. Prominent among new concerns were the environmental effects of nutrient export from farm fields. Traditional conservation practices used to control surface water runoff and erosion control were mitigating a significant portion of these nutrient losses. Additional gains were being achieved using nutrient management practices—application of nutrients (appropriate timing, rate, method, and form) to minimize losses to the environment and maximize the availability of nutrients for crop growth.

Summary of Practice Use

Given the long history of conservation in the Missouri River Basin, it is not surprising to find that nearly all cropped acres in the region have evidence of some kind of conservation practice, especially erosion control practices. The conservation practice information collected during the study was used to assess the extent of conservation practice use. Key findings are the following.

- Structural practices for controlling water erosion are in use on 41 percent of cropped acres. On the 40 percent of cropped acres designated as highly erodible land, structural practices designed to control water erosion are in use on 49 percent of those acres. Structural practice use is more prevalent in the eastern portion of the basin, where 48 percent of cropped acres, including 73 percent of highly erodible land, have one or more structural conservation practice in use.
- Reduced tillage is common in the region; 93 percent of the cropped acres meet criteria for either no-till (46 percent) or mulch till (47 percent). All but 3 percent of the acres had evidence of some kind of reduced tillage on at least one crop.
- About 60 percent of cropped acres are gaining soil organic carbon, including 84 percent of cropped acres in the eastern portion of the region and 42 percent in the western portion.

- Producers use either residue and tillage management practices or structural practices, or both, on 98 percent of the acres.
- Nutrient management practices are widely used on cropped acres in the Missouri River Basin.
  - 72 percent of cropped acres meet criteria for timing of nitrogen applications on all crops and 75 percent of cropped acres meet criteria for timing of phosphorus applications on all crops.
  - 61 percent of cropped acres meet criteria for method of nitrogen application on all crops and 70 percent meet criteria for method of phosphorus application on all crops.
  - 62 percent of cropped acres meet criteria for nitrogen application rate on all crops and 41 percent meet criteria for phosphorus application rates for the full crop rotation.
- Although most cropped acres meet nutrient management criteria for rate, timing, or method, fewer acres meet criteria for all three:
  - 35 percent of cropped acres meet all criteria for nitrogen applications, including 43 percent of cropped acres in the eastern portion of the basin;
  - 41 percent of cropped acres meet all criteria for phosphorus applications, including 45 percent of cropped acres in the western portion of the basin; and
  - 24 percent of cropped acres meet criteria for *both* phosphorus and nitrogen, including 27 percent of cropped acres in the eastern portion of the basin.
- During the 2003–06 period of data collection cover crops were used on less than 1 percent of the acres in the region.
- An Integrated Pest Management (IPM) indicator showed that only about 7 percent of the acres were being managed at a relatively high level of IPM.
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of about 1.1 million acres in the region, of which 72 percent is highly erodible land.

Structural Conservation Practices

Data on structural practices for the farm field associated with each sample point were obtained from four sources:

1. **The NRI-CEAP Cropland Survey** included questions about the presence of 12 types of structural practices: terraces, grassed waterways, vegetative buffers (in-field), hedgerow plantings, riparian forest buffers, riparian herbaceous buffers, windbreaks or herbaceous wind barriers, contour buffers (in-field), field borders, filter strips, critical area planting, and grade stabilization structures.
2. For fields with conservation plans, **NRCS field offices** provided data on all structural practices included in the plans.
3. **The USDA Farm Service Agency** (FSA) provided practice information for fields that were enrolled in the Continuous CRP for these structural practices: contour grass strips, filter strips, grassed waterways, riparian buffers (trees), and field windbreaks (Alex Barbarika, USDA/FSA, personal communication).
4. **The 2003 NRI** provided additional information for practices that could be reliably identified from aerial photography as part of the NRI data collection process. These practices include contour buffer strips, contour farming, contour stripcropping, field stripcropping, terraces, cross wind stripcropping, cross wind trap strips, diversions, field borders, filter strips, grassed waterways or outlets, hedgerow planting, herbaceous wind barriers, riparian forest buffers, and windbreak or shelterbelt establishment.

Overland flow control practices are designed to slow the movement of water across the soil surface to reduce surface water runoff and sheet and rill erosion. NRCS practice standards for overland flow control include terraces, contour farming, stripcropping, in-field vegetative barriers, and field borders. These practices are found on about 32 percent of the cropped acres in the region, including 41 percent of the highly erodible land (HEL), with about equal use in both the eastern and western portions (table 7). Overland flow control practices are more prevalent on HEL in the eastern portion of the region; of the 11.4 million acres of HEL in the eastern portion, 63 percent have overland flow control practices. In the western portion, 29 percent of 22.0 million HEL acres have overland flow control practices.

Concentrated flow control practices are designed to prevent the development of gullies along flow paths within the field. NRCS practice standards for concentrated flow control practices include grassed waterways, grade stabilization structures, diversions, and water and sediment control basins. About 21 percent of the cropped acres have one or more of these practices, including 27 percent of the HEL (table 7). Concentrated flow control practices are more prevalent on HEL in the eastern portion of the region, where they are in use on 49 percent of HEL acres. In the western portion, concentrated flow control practices are used on 15 percent of the HEL acres and 13 percent of the non-HEL acres.

Edge-of-field buffering and filtering practices, consisting of grasses, shrubs, and/or trees, are designed to capture the surface runoff losses that were not avoided or mitigated by the in-field practices. NRCS practice standards for edge-of-field mitigation practices include edge-of-field filter strips, riparian herbaceous buffers, and riparian forest buffers. CRP's buffer practices are included in this category. Edge-of-field buffering and filtering practices are in use on only about 3 percent of all cropped acres in the region (table 7), with more use in the eastern portion of the basin than in the western portion.

Overall, about 41 percent of the cropped acres in the Missouri River Basin are treated with one or more of these water erosion control structural practices (table 7), with more use in the eastern portion of the basin. Water erosion control structural practices are in use on 48 percent of cropped acres in the eastern portion, including 73 percent of HEL acres. In the western portion, 36 percent of cropped acres are treated with one or more of these practices, including 37 percent of HEL acres.

Table 7. Structural conservation practices in use for cropped acres, baseline conservation condition, Missouri River Basin

	Percent of non-HEL acres			Percent of HEL acres			Percent of cropped acres		
Structural conservation practice in use	Eastern portion	Western portion	Entire region	Eastern portion	Western portion	Entire region	Eastern portion	Western portion	Entire region
Overland flow control practices:Terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, in-field vegetative barriers	23	31	27	63	29	41	35	30	32
Concentrated flow control practices: Grassed waterways, grade stabilization structures, diversions, other structures for water control	22	13	17	49	15	27	30	14	21
Edge-of-field buffering and filtering practices: Riparian forest buffers, riparian herbaceous buffers, filter strips	7	1	4	5	1	2	6	1	3
Overland flow, concentrated flow, or edge-of-field practice	36	36	36	73	37	49	48	36	41
Wind erosion control practices: Windbreaks/shelterbelts, cross wind trap strips, herbaceous windbreak, hedgerow planting	9	9	9	5	17	12	7	13	10

Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.
Note: About 40 percent of cropped acres in the Missouri River Basin are highly erodible land (HEL), 31 percent in the eastern portion and 47 percent in the western portion. Soils are classified as HEL if they have an erodibility index (EI) score of 8 or higher. A numerical expression of the potential of a soil to erode, EI considers the physical and chemical properties of the soil and climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped.

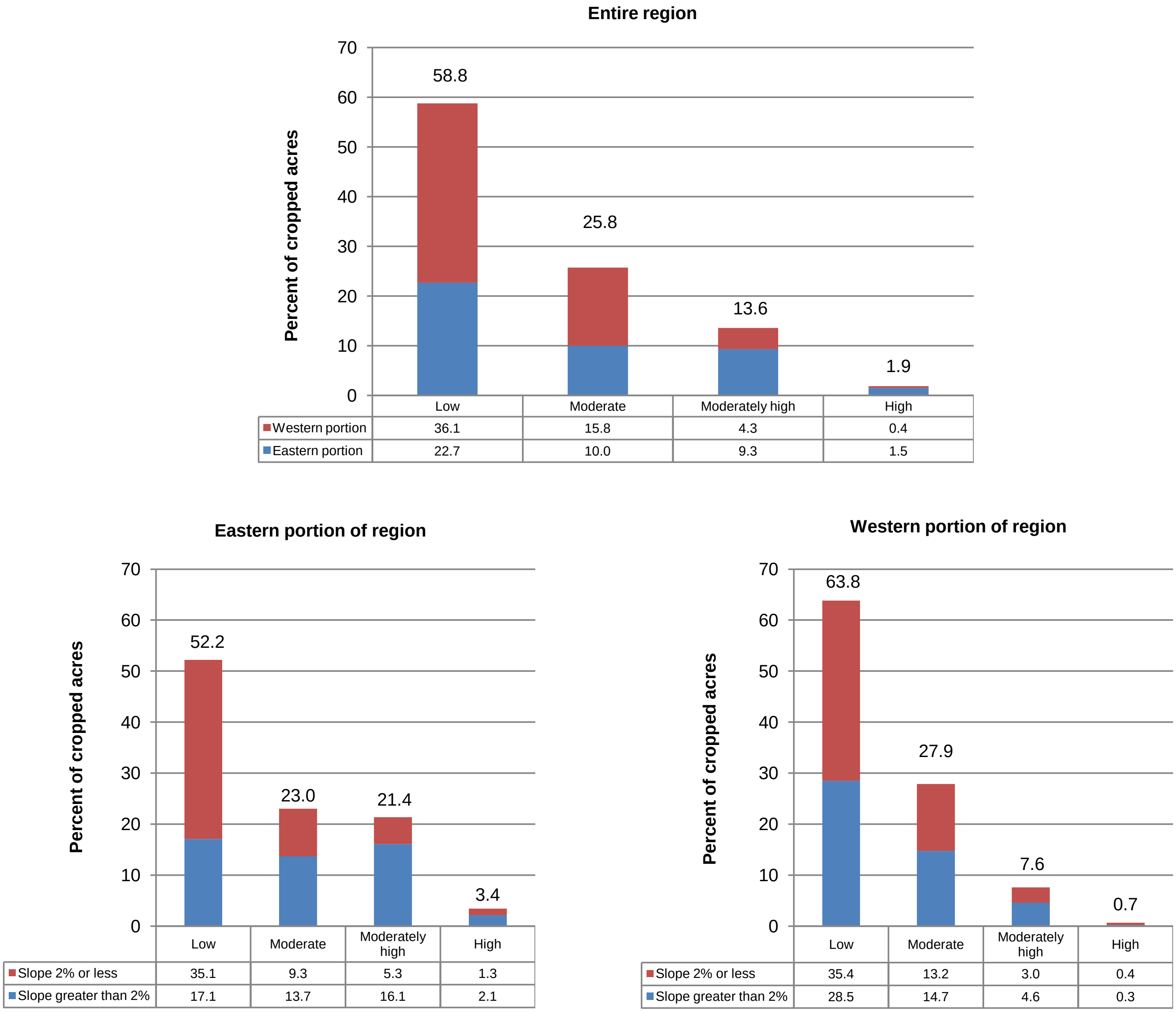
About 59 percent of the acres in this region do not have structural practices for water erosion control. Many of these acres may not need structural practices. Of the acres without structural practices, about 61 percent have slopes less than 2 percent. Overall, about 52 percent of cropped acres in the region have slopes less than 2 percent, with about the same proportion in both the eastern and western portions.

To evaluate the overall use of structural practices for water erosion control, practice use was classified as high, moderately high, moderate, or low for each sample point according to criteria presented in figure 9. About 15.5 percent of cropped acres in the region have a high or moderately high level of treatment within the region. This percentage is 24.8 percent in the eastern portion compared to 8.3 percent in the western portion.

These structural practice treatment levels were combined with use of residue and tillage management practices to estimate conservation treatment levels for water erosion control in chapter 5, where criteria for points with slopes less than 2 percent did not include structural practice use.

Wind erosion control practices are designed to reduce the force of the wind on the field. NRCS structural practices for wind erosion control include cross wind ridges, cross wind trap strips, herbaceous wind barriers, and windbreak or shelterbelt establishment. Wind erosion is a significant resource concern for this region. About 10 percent of the cropped acres in the region are treated for wind erosion using structural practices (table 7).

Figure 9. Percent of cropped acres at four conservation treatment levels for structural practices, baseline conservation condition, Missouri River Basin



Criteria for four levels of treatment with structural conservation practices are:

- **High treatment**: Edge-of-field mitigation *and* at least one in-field structural practice (concentrated flow or overland flow practice) required.
- **Moderately high treatment**: Either edge-of-field mitigation required or both concentrated flow and overland flow practices required.
- **Moderate treatment**: No edge-of-field mitigation, either concentrated flow or overland flow practices required.
- **Low treatment**: No edge-of-field or in-field structural practices.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.
Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.

Residue and Tillage Management Practices

Simulations of the use of residue and tillage management practices were based on the field operations and machinery types reported in the NRI-CEAP Cropland Survey for each sample point. The survey obtained information on the timing, type, and frequency of each tillage implement used during the previous 3 years, including the crop to which the tillage operation applied. Model outcomes affected by tillage practices, such as erosion and runoff, were determined based on APEX processes of the daily tillage activities as reported in the survey.

To evaluate the level of residue and tillage management, the Soil Tillage Intensity Rating (STIR) (USDA/NRCS 2007) was used for tillage intensity and gains or losses in soil organic carbon (based on model simulation results) were used as an indicator of residue management.

STIR values represent the soil disturbance intensity, which was estimated for each crop at each sample point.[5] The soil disturbance intensity is a function of the kinds of tillage, the frequency of tillage, and the depth of tillage. STIR values were calculated for each crop and for each of the 3 years covered by the NRI-CEAP Cropland Survey (accounting for multiple crops or cover crops). By combining the STIR values for each crop year with model output on the long-term trend in soil organic carbon gain or loss, eight categories of residue and tillage management were identified, as defined in table 8.[6]

Overall, 93 percent of cropped acres in the Missouri River Basin meet the tillage intensity rating for either no-till or mulch till (table 8). About 46 percent meet the criteria for no-till—32 percent of cropped acres with gains in soil organic carbon and 24 percent with soil organic carbon loss. About 47 percent meet the tillage intensity criteria for mulch till—25.3 percent of cropped acres with gains in soil organic carbon and 21.3 percent with soil organic carbon loss. About 4 percent of cropped acres did not meet criteria for mulch till or no-till but had reduced tillage on some crops in the rotation. Only 3 percent of the acres are conventionally tilled for all crops in the rotation.

No-till and mulch till use was about the same in both the eastern and western portions of the basin. However, more acres had gains in soil organic carbon in the eastern portion than in the western portion. In the eastern portion, 84 percent of cropped acres had gains in soil organic carbon according to the model simulations. In the western portion, however, only 42 percent had gains in soil organic carbon.

To evaluate the use of residue and tillage management practices, practice use was classified as high, moderately high, moderate, or low for each sample point according to criteria presented in figure 10. The high and moderately high treatment levels represent the 57 percent of cropped acres that meet tillage intensity criteria for either no-till or mulch till with gains in soil organic carbon.

The high treatment level (52 percent of the acres) includes only those acres where the tillage intensity criteria are met for *each* crop in the rotation. Criteria for the high treatment level were met for 76 percent of cropped acres in the eastern portion of the basin, compared to 33 percent in the western portion.

About 41 percent of cropped acres have a moderate level of treatment because some crops have reduced tillage but do not meet criteria for no-till or mulch till or they are gaining soil organic carbon but tillage intensity exceeds criteria for mulch till (fig. 10). Less than 2 percent of the acres have a low treatment level, consisting of continuous conventional tillage for all crops in the rotation and loss of soil organic carbon.

These residue and tillage management treatment levels were combined with the use of structural practices to estimate conservation treatment levels for water erosion control in chapter 5.

Structural practices and residue and tillage management practices influence losses of sediment, nutrients, and pesticides due to water erosion. Most of the cropped acres (98 percent) in the Missouri River Basin have one or both of these types of water erosion control practices (table 9). About 38 percent meet tillage intensity for no-till or mulch till *and* have structural practices, including 32 percent of cropped acres in the eastern portion and 46 percent of cropped acres in the western portion. About 55 percent of cropped acres meet tillage criteria without structural practices in use. Only 2 percent have structural practices without any kind of residue or tillage management.

[5] Percent residue cover was not used to evaluate no-till or mulch till because this criterion is not included in the current NRCS practice standard for Residue and Tillage Management. Residue is, however, factored into erosion and runoff estimates in APEX.

[6] STIR values in combination with carbon trends are in line with the use of the Soil Conditioning Index (SCI), which approximates the primary criteria for NRCS residue management standards. The NRCS practice standard, as applied at the field, may include other considerations to meet site specific resource concerns that are not considered in this evaluation.

Table 8. Residue and tillage management practices for the baseline conservation condition based on STIR ratings for tillage intensity and model output on carbon gain or loss, Missouri River Basin

Residue and tillage management practice in use	Percent of cropped acres in eastern portion	Percent of cropped acres in western portion	Percent of all cropped acres
All acres			
Average annual tillage intensity for crop rotation meets criteria for no-till*	47.8	45.2	46.3
Average annual tillage intensity for crop rotation meets criteria for mulch till**	48.0	45.4	46.5
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	2.0	5.5	4.0
Continuous conventional tillage in every year of crop rotation***	2.2	3.9	3.2
Total	100.0	100.0	100.0
Acres with carbon gain			
Average annual tillage intensity for crop rotation meets criteria for no-till*	41.7	24.5	32.0
Average annual tillage intensity for crop rotation meets criteria for mulch till**	39.5	14.3	25.3
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	1.0	1.1	1.1
Continuous conventional tillage in every year of crop rotation***	1.5	1.9	1.7
Total	83.6	41.8	60.0
Acres with carbon loss			
Average annual tillage intensity for crop rotation meets criteria for no-till*	6.1	20.7	14.3
Average annual tillage intensity for crop rotation meets criteria for mulch till**	8.5	31.1	21.3
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	1.0	4.4	2.9
Continuous conventional tillage in every year of crop rotation***	0.7	2.1	1.5
Total	16.4	58.2	40.0

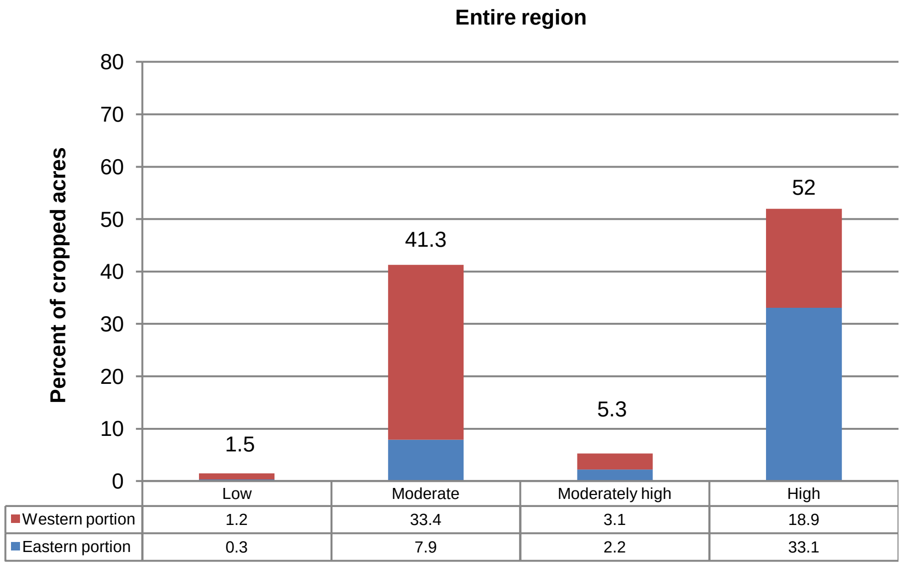
* Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is less than 30.
** Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is between 30 and 100.
*** Soil Tillage Intensity Rating (STIR) for every crop year in the rotation is more than 100.
Note: A description of the Soil Tillage Intensity Rating (STIR) can be found at http://stir.nrcs.usda.gov/.
Note: Percents may not add to totals because of rounding.
Note: Percent residue cover was not used to determine no-till or mulch till.
Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.

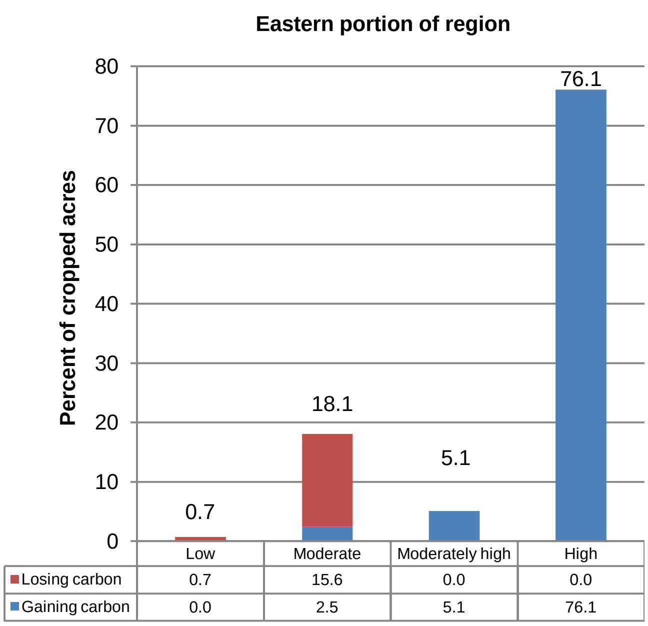
Table 9. Percent of cropped acres with water erosion control practices for the baseline conservation condition, Missouri River Basin

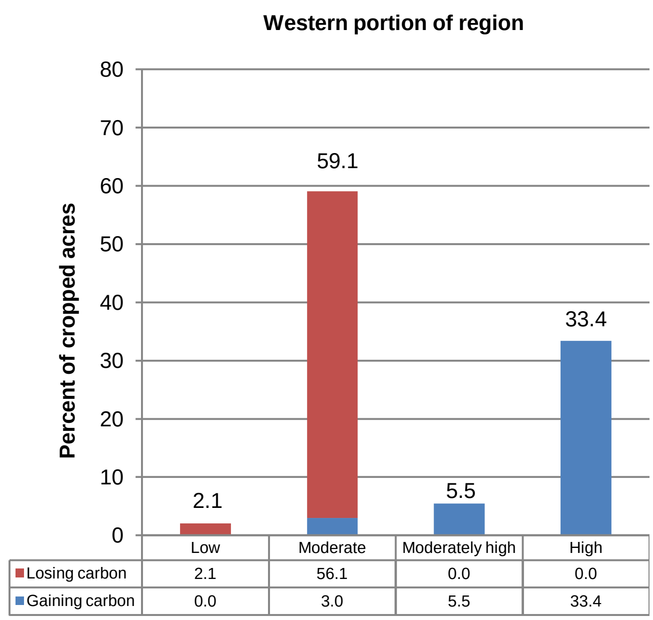
Conservation treatment	Percent of cropped acres in eastern portion	Percent of cropped acres in western portion	Percent of all cropped acres
No-till or mulch till with carbon gain, no structural practices	27	42	34
No-till or mulch till with carbon loss, no structural practices	31	8	21
Some crops with reduced tillage, no structural practices	4	1	2
Structural practices and no-till or mulch till with carbon gain	11	39	23
Structural practices and no-till or mulch till with carbon loss	21	7	15
Structural practices and some crops with reduced tillage	2	1	2
Structural practices only	2	1	2
No water erosion control treatment	2	1	2
All acres	100	100	100

Note: Percents may not add to totals because of rounding.

Figure 10. Percent of cropped acres at four conservation treatment levels for residue and tillage management, baseline conservation condition, Missouri River Basin







Criteria for four levels of treatment with residue and tillage management are:

- **High treatment**: *All crops* meet tillage intensity criteria for either no-till or mulch till and crop rotation is gaining soil organic carbon.
- **Moderately high treatment**: *Average annual* tillage intensity meets criteria for mulch till or no-till and crop rotation is gaining soil organic carbon; some crops in rotation exceed tillage intensity criteria for mulch till.
- **Moderate treatment**: Some crops have reduced tillage but tillage intensity exceeds criteria for mulch till or crop rotation is gaining soil organic carbon and tillage intensity exceeds criteria for mulch till; most acres in this treatment level are losing soil organic carbon.
- **Low treatment**: Continuous conventional tillage and crop rotation is losing soil organic carbon.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.
Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.

Conservation Crop Rotation

In the Missouri River Basin, crop rotations that meet NRCS criteria (NRCS practice code 328) occur on about 88 percent of the cropped acres. This practice consists of growing different crops in a planned rotation to manage nutrient and pesticide inputs, enhance soil quality, or reduce soil erosion. Including hay or a close grown crop in rotations with row crops can have a pronounced effect on long-term average field losses of sediment and nutrients, as well as enhancement of soil quality.

The model outputs reported in chapter 4 reflect the effects of conservation crop rotations. However, the benefits of conservation crop rotation practices could not be assessed quantitatively in this study for two reasons. First, it was not possible to differentiate conservation crop rotations from crop rotations for other purposes, such as the control of pests or in response to changing markets. Second, the "no-practice scenario" would require simulation of mono-cropping systems. Not only was there inadequate information on chemical use and other farming practices for widespread mono-crop production, but arbitrary decisions about which crops to simulate at each sample point would be required to preserve the level of regional production.

Cover Crops

Cover crops are planted when the principal crops are not growing. The two most important functions of cover crops from a water quality perspective are (1) to provide soil surface cover and reduce soil erosion, and (2) to utilize and convert excess nutrients remaining in the soil from the preceding crop into plant biomass, thereby reducing nutrient leaching and minimizing the amount of soluble nutrients in runoff during the non-crop growing season. From a soil quality perspective, cover crops help capture atmospheric carbon in plant tissue, provide habitat for the soil food web, and stabilize or enhance soil aggregate strength.

The presence or absence of cover crops was determined from farmer responses in the NRI-CEAP Cropland Survey. The following criteria were used to identify a cover crop.

- A cover crop must be a close-grown crop that is not harvested as a principal crop, or if it is harvested, must have been specifically identified in the NRI-CEAP Cropland Survey as a cover crop to indicate that the harvest was for an acceptable purpose (such as biomass removal or use as mulch or forage material).
- Spring-planted cover crops are inter-seeded into a growing crop or are followed by the seeding of a summer or late fall crop that may be harvested during that same year or early the next year.
- Late-summer-planted cover crops are followed by the harvest of another crop in the same crop year or the next spring.
- Fall-planted cover crops are followed by the spring planting of a crop for harvest the next year.

Some cover crops are planted for soil protection during establishment of spring crops such as sugar beets and potatoes. Early spring vegetation protects young crop seedlings.

In the Missouri River Basin, cover crops were not commonly used as a conservation practice during the period covered by the farmer survey (2003–06). Less than 1 percent of the acres (12 sample points) met the above criteria for cover crop use in this region.

Irrigation Management Practices

Irrigation in the United States has its roots in the arid West where precipitation is insufficient to meet the needs of growing crops. In other parts of the United States, rainfall totals are sufficient in most years to produce satisfactory yields. The distribution of the rainfall during the crop growing season, however, is sometimes problematic, especially in years when precipitation is below average. In these cases, irrigation applications are sometimes used to supplement natural rainfall. This supplemental irrigation water can overcome soil moisture deficiencies during drought stress periods and improve yields. Natural rainfall in the Missouri River Basin varies from a few inches to more than 40 inches, generally increasing from the west to east across the Basin, so irrigation is essential for crop growth in some areas and is used as a supplemental supply in other areas.

Irrigation applications are made with either a pressure or a gravity system. Gravity systems, as the name implies, utilizes gravitational energy to move water from higher elevations to lower elevations, such as moving water from a ditch at the head of a field, across the field to the lower end. Pumps are most often used to create the pressure in pressure systems, and the water is applied under pressure through pipes and nozzles of one form or another. There are also variations such as where water is diverted at higher elevations and the pressure head created by gravity is substituted for the energy of a pump.

Proper irrigation involves applying appropriate amounts of water to the soil profile to reduce any plant stress while at the same time minimizing water losses through evaporation, deep percolation, and runoff. Conversion of much of the gravity irrigated area to pressure systems and the advent of pressure systems in rain-fed agricultural areas has reduced the volumes of irrigation water lost to deep percolation and end-of-field runoff, but has greatly increased the volume of water lost to evaporation in the pressurized sprinkling process. Modern sprinklers utilize improved nozzle technology to increase droplet size as well as reduce the travel time from the nozzle to the ground. Irrigation specialists consider the center pivot or linear move sprinkler with low pressure spray and low flow systems such as drip and trickle systems as the current state of the art.

According to the NRI-CEAP cropland survey, about 14.3 percent of cropped acres—11.9 million acres—receive irrigation water in the Missouri River Basin for one or more crops. About 11 percent of cropped acres in the eastern portion of the basin are irrigated and 17 percent in the western portion.

To evaluate the efficiency of irrigation systems, a single measure of over-all irrigation efficiency was developed—Virtual Irrigation System Efficiency (VISE), VISE consists of three variables with values unique to each of nineteen types of irrigation systems. The first of the three variables is an application efficiency, which accounts for some losses from the on-farm conveyance system, the field conveyance mechanism, and as the water is applied to the field. In sprinkler systems this loss could be high due to evaporation. Application efficiency could also be elevated by leaky pipelines or ditches in more porous soils. The second factor is a coefficient that accounts for the loss of water below the root-zone, or deep percolation, during the irrigation process. In gravity systems deep percolation is normally much higher at the upper end of the field and lessens toward the lower end of the field. The deep percolation coefficient insures that enough water is applied so that the profile is at least filled all across the field, even if that requires excess applications to some parts of the field. The third factor accounts for the percent of water running off the edge of the field. The CEAP surveys reported few fields with runoff, even with gravity systems. While there is likely more runoff than reported, the survey values were used to define the baseline system.

Approximately 70 percent (8.3 million acres) of the irrigation in the Missouri River Basin is by pressure systems and 30 percent (3.6 million acres) is irrigated with gravity systems. Most common pressure systems are center-pivot or linear-move systems with low pressure spray (43.3 percent of irrigated acres) followed by center-pivot or linear-move systems with impact sprinkler heads (22.4 percent of irrigated acres). There are lesser numbers of center pivots or linear move systems with near ground emitters, side roll or wheel lines, solid set, and hand move sprinkler systems. Other pressure systems include 30,000 acres of the highly efficient low flow irrigation which includes drip and trickle systems. Common gravity irrigation systems include gated pipe (19 percent of irrigated acres), open discharges (4.5 percent of irrigated acres), siphon tubes from lined and unlined ditches (3.9 percent), and numerous other gravity systems. The open discharge category can include little controlled direct discharge from a well, discharge from large irrigation structures, or discharge from alfalfa valves. Approximately 46 percent of the irrigation systems in the Missouri River Basin are capable of irrigation efficiencies that would be considered appropriate for state-of-the-art irrigation.

Nutrient Management Practices

Nitrogen and phosphorus are essential inputs to profitable crop production. Farmers apply these nutrients to the land as commercial fertilizers and manure to promote plant growth and increase crop yields. Not all of the nutrients applied to the land, however, are taken up by crops; some are lost to the environment, which can contribute to offsite water quality problems.

Sound nutrient management systems can minimize nutrient losses from the agricultural management zone while providing adequate soil fertility and nutrient availability to ensure realistic yields. (The agricultural management zone is defined as the zone surrounding a field that is bounded by the bottom of the root zone, edge of the field, and top of the crop canopy.) Such systems are tailored to address the specific cropping system, nutrient sources available, and site characteristics of each field. Nutrient management systems have four basic criteria for application of commercial fertilizers and manure.[7]

1. Apply nutrients at the **appropriate rate** based on soil and plant tissue analyses and realistic yield goals.
2. Apply the **appropriate form** of fertilizer and organic material with compositions and characteristics that resist nutrient losses from the agricultural management zone.
3. Apply at the **appropriate time** to supply nutrients to the crop when the plants have the most active uptake and biomass production, and avoid times when adverse weather conditions can result in large losses of nutrients from the agricultural management zone.
4. Apply using the **appropriate application method** that provides nutrients to the plants for rapid, efficient uptake and reduces the exposure of nutrient material to forces of wind and water.

Depending on the field characteristics, these nutrient management techniques can be coupled with other conservation practices such as conservation crop rotations, cover crops, residue management practices, and structural practices to minimize the potential for nutrient losses from the agricultural management zone. Even though nutrient transport and losses from agricultural fields cannot be completely eliminated, they can be minimized by careful management and kept within an acceptable level.

The presence or absence of nutrient management practices was based on information on the timing, rate, and method of application for manure and commercial fertilizer as reported by the producer in the NRI-CEAP Cropland Survey. The appropriate form of nutrients applied was not evaluated because the survey was not sufficiently specific about the material formulations that were applied. The following criteria were used to identify the appropriate rate, time, and method of nutrient application for each crop or crop rotation.

- All commercial fertilizer and manure applications are within 3 weeks prior to plant date, at planting, or within 60 days after planting.
- The method of application for commercial fertilizer or manure is some form of incorporation or banding or spot treatment or foliar applied.

[7] These criteria are also referred to as “4R nutrient stewardship—right rate, right time, right place, and right source” (Bruulsema et al. 2009).

- The rate of nitrogen application, including the sum of both commercial fertilizer and manure nitrogen available for crops in the year of application, is—
  - o less than 1.4 times the amount of nitrogen removed in the crop yield at harvest for *each* crop[8], except for wheat and other small grain crops, and
  - o less than 1.6 times the amount of nitrogen removed in the crop yield at harvest for wheat and other small grain crops (barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale).
- The rate of phosphorus application summed over all applications and crops in the rotation, including both commercial fertilizer and manure phosphorus, is less than 1.1 times the amount of phosphorus removed in the crop yields at harvest summed over all crops in the rotation.

Phosphorus application rate criteria apply to the *full crop rotation* to account for infrequent applications intended to provide phosphorus for multiple crops or crop years, which is often the case with manure applications. Nitrogen application rate criteria apply to *each* crop in the rotation.

These nutrient management criteria are intended to represent practice recommendations commonly found in comprehensive nutrient management conservation plans and generally are consistent with recommended rates. While consistent with NRCS standards, they do not necessarily represent the best possible set of nutrient management practices. For example, lower application rates are possible when timing and method criteria are also met and when soil erosion and runoff are controlled.

Nutrient management practices are widely used on cropped acres in the Missouri River Basin, as shown in table 10.
- 72 percent of cropped acres meet criteria for timing of nitrogen applications on all crops and 75 percent of cropped acres meet criteria for timing of phosphorus applications on all crops.
- 61 percent of cropped acres meet criteria for method of nitrogen application on all crops and 70 percent meet criteria for method of phosphorus application on all crops.
- 63 percent of cropped acres meet criteria for nitrogen application rate on all crops and 56 percent meet criteria for phosphorus application rates for the full crop rotation.

These percentages of cropped acres meeting nutrient management criteria were higher in the western portion of the basin than in the eastern portion with the exception of the percent of acres meeting the phosphorus rate of application, which was higher in the eastern portion (table 10).

Only 2 percent of cropped acres have no nitrogen applied and less than 1 percent have no phosphorus applied in the model simulations.

[8] The 1.4 ratio of application rate to yield represents 70-percent use efficiency for applied nitrogen, which has traditionally been accepted as good nitrogen management practice. The 30 percent "lost" includes plant biomass left in the field, volatilization during and following application, immobilization by soil and soil microbes, and surface runoff and leaching losses. A slightly higher ratio is used for small grain crops to maintain yields at current levels.

Fall applications still occur on some acres. Nutrients applied in the fall for spring-planted crops are generally more susceptible to environmental losses than spring applications. Based on the survey, about 16 percent of the cropped acres in the Missouri River Basin receive fall applications of either commercial nitrogen fertilizer or manure on at least one crop in the rotation, excluding cases where a fall crop was planted. About 11 percent of cropped acres receive fall applications of either commercial phosphorus fertilizer or manure on at least one crop in the rotation, excluding cases where a fall crop was planted.

According to the NRI-CEAP cropland survey, only about 5.4 percent of cropped acres (4.5 million acres) have manure applied in this region. Two-thirds of the land application of manure is in the eastern portion of the basin, where 8 percent of cropped acres receive manure. The highest percentages of cropped acres with manure applied are in four subregions: the Missouri-Little Sioux River Basin (code 1023) with 16 percent, the Missouri-Big Sioux-Lewis-Clark Lake (code 1017) with 16 percent, the Loup River Basin (code 1021) with 13 percent, and the Lower Yellowstone River Basin (code 1010) with 11 percent (Appendix B, table B1).

Although most cropped acres meet nutrient management criteria for rate, timing, or method, fewer acres meet criteria for all three (table 10):
- 35 percent of cropped acres meet all criteria for nitrogen applications, including 43 percent of cropped acres in the western portion of the basin;
- 41 percent of cropped acres meet all criteria for phosphorus applications, including 45 percent of cropped acres in the eastern portion of the basin; and
- 24 percent of cropped acres meet criteria for *both* phosphorus and nitrogen applications, including 27 percent of cropped acres in the western portion of the basin.

Lower nitrogen rate criteria are appropriate for acres that meet application timing and method criteria and also are fully treated for soil erosion control because more of the nitrogen applied is retained on the field and is therefore available for crop growth. In the simulation of additional soil erosion control and nutrient management (full treatment) in chapter 6, the rates of nitrogen application, including both commercial fertilizer and manure nitrogen, were proportionately reduced to the following levels—
- 1.2 times the amount of nitrogen removed in the crop yield at harvest for *each* crop, except for wheat and small grain crops, and
- 1.5 times the amount of nitrogen removed in the crop yield at harvest for wheat and small grain crops.

About 19 percent of cropped acres in the region meet *all* nutrient management criteria including these lower nitrogen rate criteria consistent with full treatment and including acres not receiving nutrient applications (table 10). This percentage was higher for the western portion of the basin (23 percent) than for the eastern portion (12 percent).

Using the evaluation criteria presented in table 10, four levels of treatment for nitrogen and phosphorus management were derived for use in evaluating the adequacy of nitrogen and phosphorus management. These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated in chapter 5. Criteria for each of the four treatment levels are presented in figures 11 and 12.

The high treatment level represents consistent use of appropriate rate, timing, and method for all crops, including the lower nitrogen application rate criteria appropriate for full conservation treatment conditions. Based on these treatment levels, about 30 percent of the acres in the Missouri River Basin have a high level of nitrogen management and about 48 percent have a high level of phosphorus management (figs. 11 and 12). This high level of treatment is more prevalent in the western portion of the basin than in the eastern portion.

Criteria for the moderately high level of treatment are based only on the rate of application, which are:

- All crops have nitrogen application rates less than 1.6 times the nitrogen in the crop yield for wheat and other small grain crops and less than 1.4 for all other crops.
- The phosphorus application rates are less than 1.1 times the phosphorus in the crop yield for the crop rotation.

About 35 percent of cropped acres in the Missouri River basin have a moderately high treatment level for nitrogen and about 15 percent have a moderately high treatment level for phosphorus. Moderately high treatment levels are more prevalent in the eastern portion of the basin than in the western portion.

The evaluation of conservation practices and associated estimates of conservation treatment needs are based on practice use derived from a farmer survey conducted during the years 2003–06. Use of conservation practices can vary year to year depending on economic and environmental factors, including changes in crop rotations in response to market conditions, year-to-year changes in weather-related factors affecting tillage, irrigation, and nutrient management, and conservation program funding levels and program rules.

Since the 2003–06 survey, States in the Missouri River Basin have continued to work with farmers to enhance conservation practice adoption in an ongoing effort to reduce nonpoint source pollution contributing to water quality concerns. As a result, some practices may currently be in wider use within the watershed than the CEAP survey shows for 2003–06. Changes in land use and cropping system in response to market conditions could also result in less use of some conservation practices.

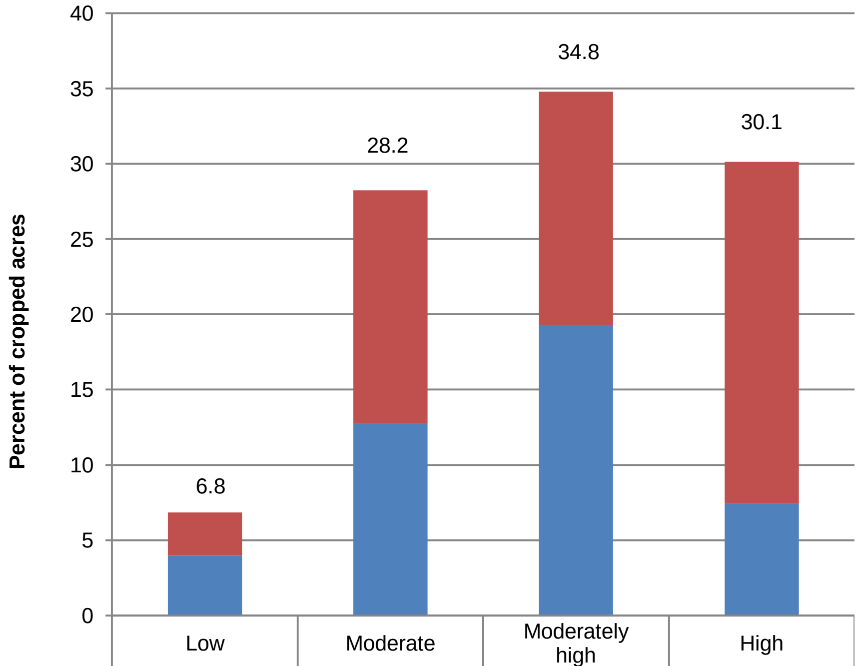
Table 10. Nutrient management practices for the baseline conservation condition, Missouri River Basin

	Percent of acres in eastern portion	Percent of acres in western portion	Percent of all cropped acres
Nitrogen*			
No N applied to any crop in rotation	3	1	2
For samples where N is applied:			
Time of application			
All crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	59	83	72
Some but not all crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	26	8	16
No crops in rotation have application of N (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	12	9	10
Method of application			
All crops in rotation have N applied with incorporation or banding/foliar/spot treatment	56	65	61
Some but not all crops in rotation have N applied with incorporation or banding/foliar/spot treatment	35	27	30
No crops in rotation have N applied with incorporation or banding/foliar/spot treatment	5	7	6
Rate of application			
All crops in rotation meet the nitrogen rate criteria described in text	58	67	63
Some but not all crops in rotation meet the nitrogen rate criteria described in text	36	29	32
No crops in rotation meet the nitrogen rate criteria described in text	2	4	3
Timing and method and rate of application			
All crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	24	43	35
Some but not all crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	61	44	51
No crops meet the nitrogen rate , timing criteria, and method criteria described above	12	12	12
Phosphorus*			
No P applied to any crop in rotation	0.3	13	7
For samples where P is applied:			
Time of application			
All crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	71	79	75
Some but not all crops have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	20	4	11
No crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	9	4	6
Method of application			
All crops in rotation have P applied with incorporation or banding/foliar/spot treatment	69	71	70
Some but not all crops in rotation have P applied with incorporation or banding/foliar/spot treatment	27	13	19
No crops in rotation have P applied with incorporation or banding/foliar/spot treatment	4	3	3
Rate of application			
Crop rotation has P applied at a rate less than 1.1 times the removal of P in the yield at harvest for the crop rotation	68	46	56
Crop rotation has P applied at a rate more than 1.1 times the removal of P in the yield at harvest for the crop rotation	31	41	37
Timing and method and rate of application			
Crop rotation has P rate less than 1.1 times removal at harvest and meet timing and method criteria described above	45	37	41
Crop rotation has P rate less than 1.1 times removal at harvest and some but not all crops meet timing and method criteria described above	21	8	13
Crop rotation has P rate more than 1.1 times removal at harvest and may or may not meet timing and method criteria described above	34	43	39
Nitrogen and Phosphorus			
Crop rotation P rate less than 1.1 and N rate criteria described in text and all applications within 3 weeks before planting or within 60 days after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied	20	27	24
Crop rotation P rate less than 1.1 and N rate criteria appropriate for full conservation treatment (see text) and all applications within 3 weeks before planting or within 60 days after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied	12	23	19
All sample points	100	100	100

Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion. Percents may not add to 100 because of rounding.

* These estimates include adjustments made to the reported data on nitrogen and phosphorus application rates from the survey because of missing data and data-entry errors. In the case of phosphorus, the 3-year data period for which information was reported was too short to pick up phosphorus applications made at 4- and 5-year intervals between applications, which is a common practice for producers adhering to sound phosphorus management techniques. Since crop growth, and thus canopy development which decreases erosion, is a function of nitrogen and phosphorus, it was necessary to add additional nitrogen and phosphorus when the reported levels were insufficient to support reasonable crop yields throughout the 47 years in the model simulation. The approach taken was to first identify crop samples that have application rates recorded erroneously or were under-reported in the survey. The model was used to identify these samples by running the simulation at optimal levels of nitrogen and phosphorus for crop growth. The set of crop samples identified were treated as if they had missing data. Additional nitrogen or phosphorus was added to these crop samples so that the total nitrogen or phosphorus use was similar to that for the unadjusted set of crop samples. About 39 percent of the acres received a nitrogen adjustment for one or more crops. About 44 percent of the acres received a phosphorus adjustment for one or more crops. Nitrogen and phosphorus were added by increasing the existing applications (thus preserving the reported timing and methods), when present, or were applied at plant. (For additional information on adjustment of nutrient application rates, see “Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling,” available at http://www.nrcs.usda.gov/technical/nri/ceap

Figure 11. Percent of cropped acres at four conservation treatment levels for nitrogen management, baseline conservation condition, Missouri River Basin



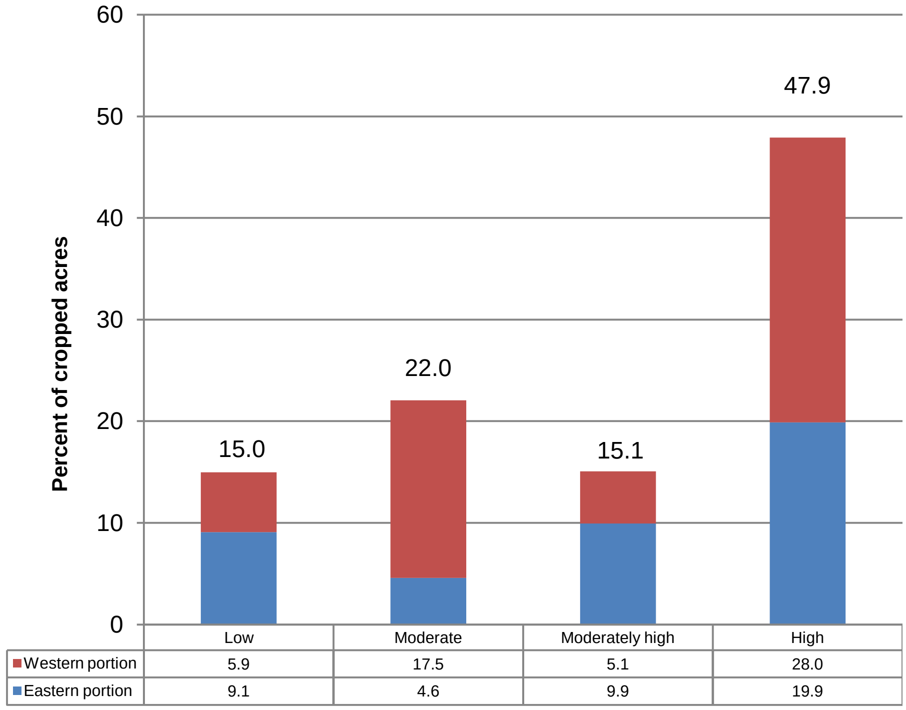
	Low	Moderate	Moderately high	High
Western portion	2.9	15.5	15.5	22.7
Eastern portion	4.0	12.7	19.3	7.5

Criteria for four levels of nitrogen management are:

- **High treatment**: All crops have: (1) total nitrogen application rates (including manure) less than 1.2 times the nitrogen in the crop yield for crops other than small grains and less than 1.5 times the nitrogen in the crop yield for small grains; (2) all applications occur within 3 weeks before planting or within 60 days after planting; and (3) all applications are incorporated or banding/foliar/spot treatment is used.
- **Moderately high treatment**: All crops have total nitrogen application rates (including manure) less than 1.4 times the nitrogen in the crop yield for crops other than small grains and less than 1.6 times the nitrogen in the crop yield for small grains. Timing and method of application criteria may or may not be met.
- **Moderate treatment**: All crops meet either the above criteria for timing *or* method, but do not meet criteria for rate.
- **Low treatment**: Some or all crops in rotation exceed criteria for rate and either timing or method.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.
Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.

Figure 12. Percent of cropped acres at four conservation treatment levels for phosphorus management, baseline conservation condition, Missouri River Basin



Criteria for four levels of phosphorus management are:

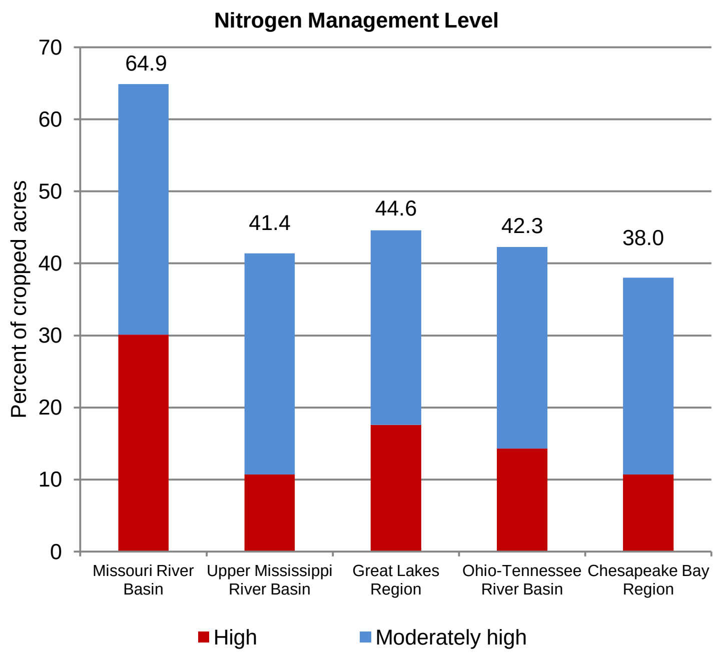
- **High treatment**: (1) total phosphorus application rates (including manure) summed over all crops are less than 1.1 times the phosphorus in the crop yields for the crop rotation, (2) all applications occur within 3 weeks before planting or within 60 days after planting, and (3) all applications are incorporated or banding/foliar/spot treatment was used. (Note that phosphorus applications for individual crops could exceed 1.1 times the phosphorus in the crop yield but total applications for the crop rotation could not.)
- **Moderately high treatment**: Total phosphorus application rates (including manure) are less than 1.1 times the phosphorus in the crop yield for the crop rotation. No method or timing of application criteria is applied.
- **Moderate treatment**: Sample points that do not meet the high or moderately high criteria but all phosphorus applications for all crops have appropriate time *and* method of application.
- **Low treatment**: All acres have excessive application rates over the crop rotation and inadequate method or timing of application for at least one crop in the rotation.

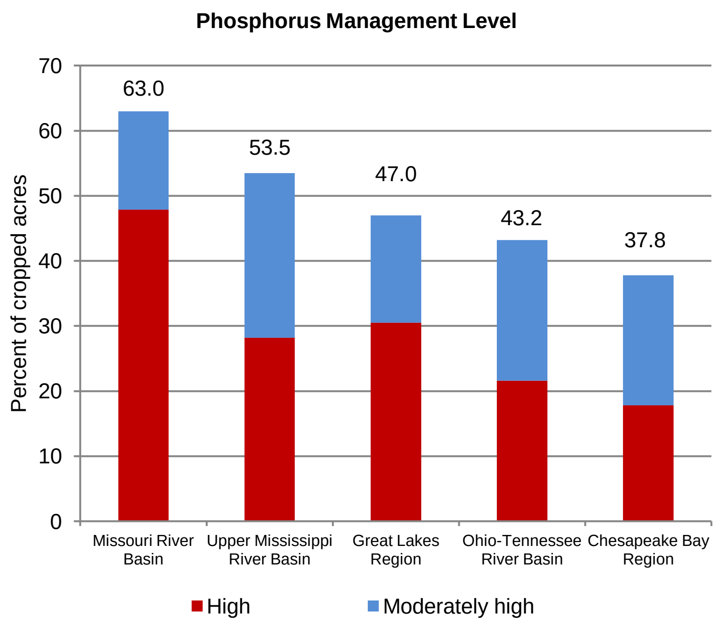
Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.
Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.

Nutrient Management in the Missouri River Basin Outpaces Other Regions

Nutrient management levels were estimated for all CEAP regions using the same criteria (figs. 11 and 12) so that regional comparisons could be made. Based on this consistent measure, the use of good nutrient management is more prevalent in the Missouri River Basin than in other regions reported to date, as shown in the graphics below. More than 60 percent of the acres meet criteria for high or moderately high levels of nitrogen or phosphorus management in the Missouri River Basin, in part because of cropping systems that are less intensely fertilized with lower application rates, drier planting seasons, and more crops harvested during the summer.

In the Missouri River Basin, about 65 percent of cropped acres have a high or moderately high level of nitrogen management, compared to percentages that range from 38 to 45 for other regions. A high or moderately high level of phosphorus management is in use on about 63 percent of cropped acres in the Missouri River Basin, compared to percentages that range from 38 to 54 for other regions.





Pesticide Management Practices

The presence or absence of pesticide management practices was based on an Integrated Pest Management (IPM) indicator developed using producer responses to the set of IPM-related questions in the NRI-CEAP Cropland Survey (table 11).[9]

Adoption of IPM systems can be described as occurring along a continuum from largely reliant on prophylactic control measures and pesticides to multiple-strategy, biologically intensive approaches. IPM adoption is not usually an either/or situation. The practice of IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environment scenario. Where appropriate, each site should have in place a management strategy for **Prevention, Avoidance, Monitoring,** and **Suppression** of pest populations (the **PAMS** approach) (Coble 1998). In order to qualify as IPM practitioners, growers would use tactics in all four PAMS components.

Prevention is the practice of keeping a pest population from infesting a field or site, and should be the first line of defense. It includes such tactics as using pest-free seeds and transplants, preventing weeds from reproducing, irrigation scheduling to avoid situations conducive to disease development, cleaning tillage and harvesting equipment between fields or operations, using field sanitation procedures, and eliminating alternate hosts or sites for insect pests and disease organisms.

Avoidance may be practiced when pest populations exist in a field or site but the impact of the pest on the crop can be avoided through some cultural practice. Examples of avoidance tactics include crop rotation in which the crop of choice is not a host for the pest, choosing cultivars with genetic resistance to pests, using trap crops or pheromone traps, choosing cultivars with maturity dates that may allow harvest before pest populations develop, fertilization programs to promote rapid crop development, and simply not planting certain areas of fields where pest populations are likely to cause crop failure.

Monitoring and proper identification of pests through surveys or scouting programs, including trapping, weather monitoring, and soil testing where appropriate, are performed as the basis for suppression activities. Records are kept of pest incidence and distribution for each field or site. Such records form the basis for crop rotation selection, economic thresholds, and suppressive actions.

Suppression of pest populations may be necessary to avoid economic loss if prevention and avoidance tactics are not successful. Suppressive tactics include *cultural* practices such as narrow row spacing or optimized in-row plant populations, alternative tillage approaches such as no-till or strip-till systems, cover crops or mulches, or using crops with allelopathic potential in the rotation. *Physical* suppression tactics include cultivation or mowing for weed control, baited or pheromone traps for certain insects, and temperature management or exclusion devices for insect and disease management. *Biological* controls, including mating disruption for insects, are alternatives to conventional pesticides, especially where long-term control of a troublesome pest species can be attained. Naturally occurring biological controls, where they exist, are important IPM tools. *Chemical pesticides* are applied as a last resort in suppression systems using a sound management approach, including selection of pesticides with low risk to non-target organisms.

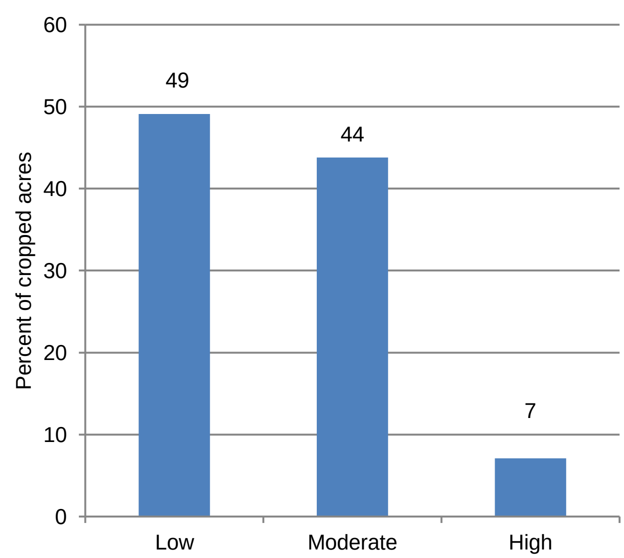
An IPM index was developed to determine the level of IPM activity for each sample point. The index was constructed as follows.

- Scores were assigned to each question by a group of IPM experts.
- Scores for each PAMS category were normalized to have a maximum score of 100.
- The four PAMS categories were also scored in terms of relative importance for an IPM index: prevention = 1/6, avoidance = 1/6, monitoring = 1/3, and suppression = 1/3.
- The IPM indicator was calculated by multiplying the normalized PAMS category by the category weight and summing over the categories.

An IPM indicator score greater than 60 defined sample points with a high level of IPM activity. Sample points with an IPM indicator score of 35 to 60 were classified as moderately high IPM treatment and sample points with an IPM score less than 35 were classified as low IPM treatment.

About 7 percent of the acres in the Missouri River Basin have a high level of IPM activity (fig. 13). About 44 percent have a moderate level of IPM activity, and 49 percent have a low level of IPM activity. The IPM indicator scores are about the same for the eastern and western portions of the region.

Figure 13. Integrated Pesticide Management indicator for the baseline conservation condition, Missouri River Basin



[9] For a full documentation of the derivation of the IPM indicator, see "Integrated Pest Management (IPM) Indicator Used in the CEAP Cropland Modeling," available at http://www.nrcs.usda.gov/technical/nri/ceap.

Table 11. Summary of survey responses to pest management questions, Missouri River Basin

Survey question	Number samples with "yes" response	Percent of cropped acres
Prevention		
Pesticides with different action rotated or tank mixed to prevent resistance	1,191	30
Plow down crop residues	578	16
Chop, spray, mow, plow, burn field edges, etc.	1,268	30
Clean field implements after use	1,457	41
Remove crop residue from field	252	7
Water management used to manage pests (irrigated samples only)	113	3
Avoidance		
Rotate crops to manage pests	2,805	69
Use minimum till or no-till to manage pests	2,346	60
Choose crop variety that is resistant to pests	1,506	35
Planting locations selected to avoid pests	454	13
Plant/harvest dates adjusted to manage pests	344	10
Monitoring		
Scouting practice: general observations while performing routine tasks	1,637	42
Scouting practice: deliberate scouting	1,734	44
--Established scouting practice used	520	13
--Scouting due to pest development model	308	7
--Scouting due to pest advisory warning	367	8
Scouting done by: (only highest of the 4 scores is used)		
--Scouting by operator	1,303	33
--Scouting by employee	25	1
--Scouting by chemical dealer	185	4
--Scouting by crop consultant or commercial scout	243	6
Scouting records kept to track pests?	636	17
Scouting data compared to published thresholds?	820	21
Diagnostic lab identified pest?	166	4
Weather a factor in timing of pest management practice	1,244	31
Suppression		
Pesticides used?	3,649	91
Weather data used to guide pesticide application	2,190	56
Biological pesticides or products applied to manage pests	275	6
Pesticides with different mode of action rotated or tank mixed to prevent resistance	1,190	30
Pesticide application decision factor (one choice only):		
--Routine treatments or preventative scheduling	1,949	47
--Comparison of scouting data to published thresholds	227	6
--Comparison of scouting data to operator's thresholds	426	12
--Field mapping or GPS	2	0
--Dealer recommendations	466	12
--Crop consultant recommendations	219	5
--University extension recommendations	9	0
--Neighbor recommendations	3	0
--"Other"	124	3
Maintain ground covers, mulch, or other physical barriers	1,801	47
Adjust spacing, plant density, or row directions	830	21
Release beneficial organisms	30	1
Cultivate for weed control during the growing season	636	16
Number of respondents	3,916	100

Note: The scores shown in this table were used to develop an IPM indicator as discussed in the text.

Conservation Cover Establishment

Establishing long-term cover of grass, forbs, or trees on a site provides the maximum protection against soil erosion. Conservation cover establishment is often used on cropland with soils that are vulnerable to erosion or leaching. The practice is also effective for sites that are adjacent to waterways, ponds, and lakes. Because these covers do not require annual applications of fertilizer and pesticides, this long-term conserving cover practice greatly reduces the loss of nitrogen and phosphorus from the site, and nearly eliminates pesticide loss. Because conservation covers are not harvested, they generate organic material that decomposes and increases soil organic carbon. For this study, the effect of a long-term conserving cover practice was estimated using acres enrolled in the General Signup of the CRP. The CRP General Signup is a voluntary program in which producers with eligible land enter into 10- to 15-year contracts to establish long-term cover to reduce soil erosion, improve water quality, and enhance wildlife habitat.

Landowners receive annual rental payments and cost-share assistance for establishing and maintaining permanent vegetative cover. To be eligible for enrollment in the CRP General Signup, the field (or tract) must meet specified crop history criteria.

Other factors governing enrollment in the CRP include natural resource-based eligibility criteria, an Environmental Benefits Index (EBI) used to compare and rank enrollment offers, acreage limits, and upper limits on the proportion of a county's cropland that can be enrolled (USDA Farm Service Agency 2004; Wiebe and Gollehon 2006). Initially, the eligibility criteria included only soil erosion rates and inherent soil erodibility. During the 1990s and to date, the eligibility criteria have continued to evolve, with increasing emphasis placed on issues other than soil erodibility. For contract offer ranking, weight was given to proposals that also benefited wildlife, air and water quality, and other environmental concerns.

As of 2003, about 31.5 million acres were enrolled in the CRP General Signup nationally (USDA/NRCS 2007). About one-third of these acres (11.2 million acres) are in the Missouri River Basin. Most (69 percent) are found in the western portion of the basin.

Approximately 72 percent of the cropland acres enrolled in the CRP in the Missouri River Basin are classified as highly erodible land. The inclusion of non-highly erodible land is due to both the expansion of enrollment eligibility criteria beyond soil erosion issues and the fact that farmers were allowed to enroll entire fields in the CRP even if only a portion of the field met the criteria. (Enrollment rules varied by signup period and eligibility criterion).

In the Missouri River Basin, 77 percent of the CRP land is planted to introduced grasses, 16 percent to native grasses, 7 percent to wildlife habitat, and about 0.5 percent to trees. The plantings designated in the NRI database for each sample point were simulated in the APEX model. However, in all cases the simulated cover was a mix of species and all points included at least one grass and one clover species.

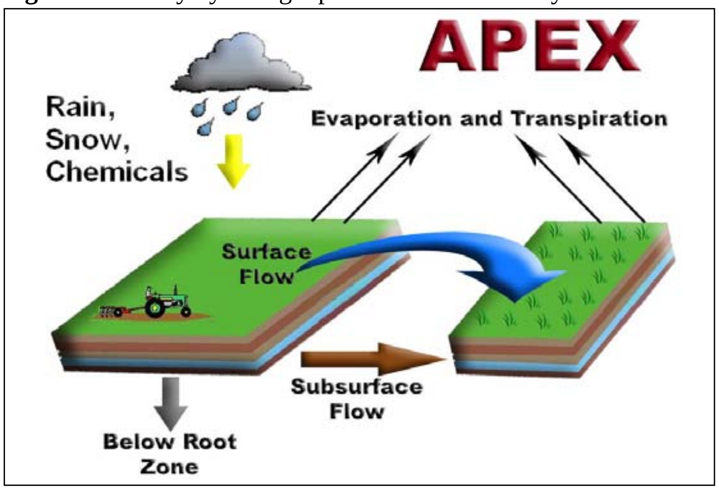
Chapter 4
Onsite (Field-Level) Effects of Conservation Practices

The Field-Level Cropland Model—APEX

A physical process model called APEX was used to simulate the effects of conservation practices at the field level (Williams et al. 2006; Williams et al. 2008; Gassman et al. 2009 and 2010).[10] The I_APEX model run management software developed at the Center for Agricultural and Rural Development, Iowa State University, was used to perform the simulations in batch mode.[11]

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides (fig. 14). The APEX model and its predecessor, EPIC (Environmental Policy Impact Calculator), have a long history of use in simulation of agricultural and environmental processes and of the effect of agricultural technology and government policy (Izaurralde et al. 2006;Williams 1990; Williams et al. 1984; Gassman et al. 2005).[12]

Figure 14. Daily hydrologic processes simulated by APEX



On a daily basis, APEX simulates the farming operations used to grow crops, such as planting, tillage before and after planting, application of nutrients and pesticides, application of manure, irrigation, and harvest. Weather events and their interaction with crop cover and soil properties are simulated; these events affect crop growth and the fate and transport of water and chemicals through the soil profile and over land to the edge of the field. Over time, the chemical makeup and physical structure of the soil may change, which in turn affect crop yields and environmental outcomes. Crop residue remaining on the field after harvest is transformed into organic matter. Organic matter may build up in the soil over time, or it may degrade, depending on climatic conditions, cropping systems, and management.

APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion, and the loss of sediment beyond the edge of the field. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field. Exchange of gaseous forms between the soil and the atmosphere is simulated, including losses of gaseous nitrogen compounds.

Irrigation, which is important for crop production in parts of the Missouri River Basin, was simulated using an "auto-irrigation" algorithm in APEX. Availability of a full irrigation water supply was assumed. When the APEX model detected water-induced yield stress above a specified threshold for irrigated fields (so indicated in the survey), it simulated the application of irrigation to the crop root-zone. The amount of irrigation water applied at each application was determined by the amount of irrigation water required to fill the root-zone, accounting for efficiency losses associated with infield transport and application. Model irrigation applications were governed by: 1) an irrigation event was simulated when actual yield was less than 95 percent of potential yield due to water stress, 2) the minimum application was 20 millimeters; 3) the annual maximum application was limited to 2,000 millimeters; and 4) at least three days had to elapse between each irrigation event.

The NRI-CEAP Cropland Survey was the primary source of information on all farming activities simulated using APEX. Crop data were transformed for the model into a crop rotation for each sample point, which was then repeated over the 47-year simulation. The 3 years of data reported in the survey were represented in the model simulation as 1-, 2-, 3-, 4-, or 5-year crop rotations. For example, a 2-year corn-soybean rotation was used if the operator reported that corn was grown in the first year, soybeans in the second year, and corn again in the third year. In this case, only 2 of the reported 3 years of survey data were used. If management differed significantly for the 2 years that corn was grown (manure was applied, for example, or tillage was different), the rotation was expanded to 4 years, retaining the second year of corn and repeating the year of soybeans. In addition, some rotations with alfalfa or grass seed were simulated as 5-year rotations. Specific rules and procedures were established for using survey data to simulate cover crops, double crops, complex systems such as intercropping and nurse crops, perennial hay in rotations, abandoned crops, re-planting, multiple harvests, manure

[10] The full theoretical and technical documentation of APEX can be found at http://epicapex.brc.tamus.edu/downloads/user-manuals.aspx.
[11] The IAPEX software steps through the simulations one at a time, extracting the needed data from the Access input tables, executes APEX, and then stores the model output in Access output files. The Web site for that software is http://www.card.iastate.edu/environment/interactive_programs.aspx.
[12] Summaries of APEX model validation studies on how well APEX simulates measured data are presented in Gassman et al. (2009) and in "APEX Model Validation for CEAP" found at http://www.nrcs.usda.gov/technical/nri/ceap.

applications, irrigation, and grazing of cropland before and after harvest.[13]

Use of conservation practices in the Missouri River Basin was obtained from four sources, as described in chapter 3: (1) NRI-CEAP Cropland Survey, (2) NRCS field offices, (3) USDA Farm Service Agency (FSA), and (4) the 2003 NRI. For each sample point, data from these four sources were pooled and duplicate practices discarded.[14]

Simulating the No-Practice Scenario

The purpose of the no-practice scenario is to provide an estimate of sediment, nutrient, and pesticide loss from farm fields under conditions without the use of conservation practices. The benefits of conservation practices in use within the Missouri River Basin were estimated by contrasting model output from the no-practice scenario to model output from the baseline conservation condition (2003–06). The only difference between the no-practice scenario and the baseline conservation condition is that the conservation practices are removed or their effects are reversed in the no-practice scenario simulations. There were usually several alternatives that could be used to represent "no practices." The no-practice representations derived for use in this study conformed to the following guidelines.

- **Consistency:** It is impossible to determine what an individual farmer would be doing if he or she had not adopted certain practices, so it is important to represent all practices on all sample points in a consistent manner that is based on the intended purpose of each practice.

- **Simplicity:** Complex rules for assigning "no-practice" activities lead to complex explanations that are difficult to substantiate and sometimes difficult to explain and accept. Complexity would not only complicate the modeling process but also hamper the interpretation of results.

- **Historical context avoided:** The no-practice scenario is a technological step backward for conservation, not a chronological step back to a prior era when conservation practices were not used. Although the advent of certain conservation technologies can be dated, the adoption of technology is gradual, regionally diverse, and ongoing. It is also important to retain the overall crop mix in the region, as it in part reflects today's market forces. Therefore, moving the clock back to 1950s (or any other time period) agriculture is not the goal of the no-practice scenario. Taking away the conservation ethic is the goal.

- **Moderation:** The no-practice scenario should provide a reasonable level of inadequate conservation so that a reasonable benefit can be determined, where warranted, but not so severe as to generate exaggerated conservation gains by simulating the worst-case condition. Tremendous benefits could be generated if, for example, nutrients were applied at twice the recommended rates with poor timing or application methods in the no-practice simulation. Similarly, large erosion benefits could be calculated if the no-practice representation for tillage was fall plowing with moldboard plows and heavy disking, which was once common but today would generally be considered economically inefficient.

- **Maintenance of crop yield or efficacy**. It is impossible to avoid small changes in crop yields, but care was taken to avoid no-practice representations that would significantly change crop yields and regional production capabilities. The same guideline was followed for pest control—the suite of pesticides used was not adjusted in the no-practice scenario because of the likelihood that alternative pesticides would not be as effective and would result in lower yields under actual conditions.

A deliberate effort was made to adhere to these guidelines to the same degree for all conservation practices so that the overall level of representation would be equally moderate for all practices.

Table 12 summarizes the adjustments to conservation practices used in simulation of the no-practice scenario.

No-practice representation of structural practices

The no-practice field condition for structural practices is simply the removal of the structural practices from the modeling process. In addition, the soil condition is changed from "Good" to "Poor" for the determination of the runoff curve number for erosion prediction.

Overland flow. This group includes such practices as terraces and contouring which slow the flow of water across the field. For the practices affecting overland flow of water and therefore the P factor of the USLE-based equations, the P factor was increased to 1. Slope length is also changed for practices such as terraces to reflect the absence of these slope-interrupting practices.

Concentrated flow. This group of practices is designed to address channelized flow and includes grassed waterways and grade stabilization structures. These practices are designed to prevent areas of concentrated flow from developing gullies or to stabilize gullies that have developed. The no-practice protocol for these practices removes the structure or waterway and replaces it with a "ditch" as a separate subarea. This ditch, or channel, represents a gully; however, the only sediment contributions from the gully will come from downcutting. Headcutting and sloughing of the sides are not simulated in APEX.

Edge of field. These practices include buffers, filters, and other practices that occur outside the primary production area and act to mitigate the losses from the field. The no-practice

[13] For a detailed description of the rules and procedures, see "Transforming Survey Data to APEX Model Input Files," http://www.nrcs.usda.gov/technical/nri/ceap.
[14] For a detailed description of the rules and procedures for simulation of structural conservation practices, see "Modeling Structural Conservation Practices in APEX," http://www.nrcs.usda.gov/technical/nri/ceap.

protocol removes these areas and their management. When the practices are removed, the slope length is also restored to the undisturbed length that it would be if the practices were not in place. (When simulating a buffer in APEX, the slope length reported in the NRI is adjusted.)

Wind control. Practices such as windbreaks or shelterbelts, cross wind ridges, stripcropping or trap strips, and hedgerows are examples of practices used for wind control. The unsheltered distance reflects the dimensions of the field as modeled, 400 meters or 1,312 feet. Any practices reducing the unsheltered distance are removed and the unsheltered distance set to 400 meters.

Table 12. Construction of the no-practice scenario for the Missouri River Basin

Practice adjusted	Criteria used to determine if a practice was in use	Adjustment made to create the no-practice scenario
Structural practices	1. Overland flow practices present	1. USLE P-factor changed to 1 and slope length increased for points with terraces, soil condition changed from good to poor.
	2. Concentrated flow—managed structures or waterways present	2. Structures and waterways replaced with earthen ditch, soil condition changed from good to poor.
	3. Edge-of-field mitigation practices present	3. Removed practice and width added back to field slope length.
	4. Wind erosion control practices present	4. Unsheltered distance increased to 400 meters
Residue and tillage management	STIR ≤100 for any crop within a crop year	Add two tandem diskings 1 week prior to planting
Cover crop	Cover crop planted for off-season protection	Remove cover crop simulation (field operations, fertilizer, grazing, etc.)
Irrigation (See text for details)	Pressure systems	East—Change to hand-move sprinkler system except where the existing system is less efficient West—Change to gravity systems except on sandy soils and steep slopes
	Gravity systems	Where conveyance is pipeline, change to gated pipe unless existing system is less efficient Where conveyance is ditch, change to unlined ditch with portals
Nitrogen rate	Total of all applications of nitrogen (commercial fertilizer and manure applications) ≤1.4 times harvest removal for non-legume crops, except for small grain crops	Increase rate to 1.68 times harvest removal (proportionate increase in all reported applications, including manure)
	Total of all applications of nitrogen (commercial fertilizer and manure applications) ≤1.6 times harvest removal for small grain crops	Increase rate to 2.0 times harvest removal (proportionate increase in all reported applications, including manure)
Phosphorus rate	Applied total of fertilizer and manure P over all crops in the crop rotation ≤ 1.1 times total harvest P removal over all crops in rotation.	Increase commercial P fertilizer application rates to reach 1.57 times harvest removal for the crop rotation (proportionate increase in all reported applications over the rotation), accounting also for manure P associated with any increase in manure applications to meet nitrogen application criteria for the no- practice scenario. Manure applications were not further increased to meet the higher P rate for the no-practice scenario.
Commercial fertilizer application method	Incorporated or banded	Change to surface broadcast
Manure application method	Incorporated, banded, or injected	Change to surface broadcast
Commercial fertilizer application timing	Within 3 weeks prior to planting, at planting, or within 60 days after planting.	Moved to 3 weeks prior to planting. Manure applications were not adjusted for timing in the no-practice scenario.
Pesticides	Practicing high level of IPM	All incorporated applications changed to surface application. For each crop, the first application event after planting and 30 days prior to harvest replicated twice, 1 week and 2 weeks later than original.
	Practicing moderate level of IPM	Same as for high level of IPM, except replication of first application only 1 time, 1 week after original
	Spot treatments	Application rates for spot treatments were adjusted upward relative to the baseline rate to represent whole-field application (see text)
	Partial field treatments	Application rates for partial field treatments were adjusted upward relative to the baseline rate to represent whole-field application (see text)

No-practice representation of conservation tillage

The no-practice tillage protocols are designed to remove the benefits of conservation tillage. For all crops grown with some kind of reduced tillage, including cover crops, the no-practice scenario simulates conventional tillage, based on the STIR (Soil Tillage Intensity Rating) value. Conventional tillage for the purpose of estimating conservation benefits is defined as any crop grown with a STIR value above 100. (To put this in context, no-till or direct seed systems have a STIR of less than 30, and that value is part of the technical standard for Residue Management, No-Till/Strip Till/Direct Seed [NRCS Practice Standard 329]). Those crops grown with a STIR value of less than 100 in the baseline conservation condition had tillage operations added in the no-practice scenario.

Simulating conventional tillage for crops with a STIR value of less than 100 requires the introduction of additional tillage operations in the field operations schedule. For the no-practice scenario, two consecutive tandem disk operations were added prior to planting. In addition to adding tillage, the hydrologic condition for assignment of the runoff curve number was changed from good to poor on all points receiving additional tillage. Points that are conventionally tilled for all crops in the baseline condition scenario are also modeled with a "poor" hydrologic condition curve number.

The most common type of tillage operation in the survey was disking, and the most common disk used was a tandem disk for nearly all crops, in all parts of the region, and for both dryland and irrigated agriculture. The tandem disk has a STIR value of 39 for a single use. Two consecutive disking operations will add 78 to the existing tillage intensity, which allows for more than 90 percent of the crops to exceed a STIR of 100 and yet maintain the unique suite and timing of operations for each crop in the rotation. Although a few sample points will have STIR values in the 80s or 90s after adding the two disking operations, the consistency of an across-the-board increase of 78 is simple and provides the effect of a distinctly more intense tillage system.

These additional two tillage operations were inserted in the simulation one week prior to planting, one of the least vulnerable times for tillage operations because it is close to the time when vegetation will begin to provide cover and protection.

No-practice representation of cover crops

The no-practice protocol for this practice removes the planting of the crop and all associated management practices such as tillage and fertilization. In a few cases the cover crops were grazed; when the cover crops were removed, so were the grazing operations.

No-practice representation of irrigation practices

The no-practice irrigation protocols were designed to remove the benefits of better water management and the increased efficiencies of modern irrigation systems. Irrigation efficiencies are represented in APEX by a combination of three coefficients that recognize water losses from the water source to the field as discussed in chapter 3: evaporation losses with sprinkler systems, percolation losses below the root-zone during irrigation, and runoff at the lower end of the field. These coefficients are combined to form an overall system efficiency that varies with soil type and land slope.

The Missouri River Basin is unique in that it is situated partly in what would be considered the supplemental irrigation area as well the traditional western irrigated area where irrigation is essential for crop production. The dividing line between the traditional irrigation area and the supplemental irrigated area runs north through central Oklahoma, Kansas, and Nebraska to the Canadian border. It represents the point where acres to the east could most likely expect substantial crop yields most years without irrigation.

The western area was treated differently from the eastern area in the spirit of developing a no-practice scenario with reasonableness as discussed previously. The irrigated fields in the supplemental irrigation area required less reduction in technology for the no-practice representation mostly because much of the supplemental irrigated area did not have a history of transitioning from gravity to pressure technology.

In the no-practice representation, all conservation practices, such as Irrigation Water Management and Irrigation Land Leveling, were removed. If the sample was pressure irrigated, the on-farm conveyance was left as reported because pressure systems were often developed along with conveyance technology that was compatible with the landscape. If the system was gravity-fed in the western part of the region, conveyance was assumed to be an open ditch in the no-practice scenario. In the area with supplemental irrigation and gravity systems, the conveyance remained unchanged unless the delivery system was a ditch. If the no-practice water delivery system was a ditch, gravity systems were simulated with unlined ditches and portals. Where the no-practice conveyance was pipelines, the gravity system reverted back to gated pipe. In the western part of the region, the pressure systems were replaced with gravity systems for no-practice scenario except on steep slopes and sandy soils where the pressure system was simulated with hand-move sprinklers. In the supplemental irrigation area, the pressure systems were also simulated with hand-move sprinklers. In cases where the efficiency of the baseline system was less than the efficiency of the no-practice system, no reduction in irrigation technology was made for the no-practice scenario.

After making the indicated adjustments to the irrigation technology, the no-practice scenario for irrigation consisted of 6.8 million acres (57 percent of the irrigated acres) of gravity systems and approximately 5.1 million acres (43 percent of irrigated acres) of pressure systems. Primary systems in the no-practice scenario are hand-move sprinklers (33 percent of irrigated acres), portals from unlined ditches (27 percent of irrigated acres), and gated pipe (24 percent of irrigated acres).

No-practice representation of nutrient management practices

The no-practice nutrient management protocols are designed to remove the benefits of proper nutrient management techniques.

The NRCS Nutrient Management standard (590) allows a variety of methods to reduce nutrient losses while supplying a sufficient amount of nutrient to meet realistic yield goals. The standard addresses nutrient loss in two primary ways: (1) by altering rates, form, timing, and methods of application, and (2) by installing buffers, filters, or erosion or runoff control practices to reduce mechanisms of loss. The latter method is covered by the structural practices protocols for the no-practice scenario. The goals of the nutrient management no-practice protocols are to alter three of the four basic aspects of nutrient application—rate, timing, and method. The form of application was not addressed because of the inability to determine if proper form was being applied.

Commercial nitrogen fertilizer rate. For the no-practice scenario, the amount of commercial nitrogen fertilizer applied was—

- increased to 1.68 times harvest removal for non-legume crops receiving less than or equal to 1.4 times the amount of nitrogen removed at harvest in the baseline scenario, except for wheat and other small grain crops; and
- increased to 2.0 times harvest removal for wheat and other small grain crops receiving less than or equal to 1.6 times the amount of nitrogen removed at harvest in the baseline scenario.

The ratio of 1.68 for the increased nitrogen rate was determined by the average rate-to-yield-removal ratio for crops exceeding the application-removal ratio of 1.4. Where nitrogen was applied in multiple applications, each application was increased proportionately.

The assessment was made on an average annual basis for each crop in the rotation using average annual model output on nitrogen removed with the yield at harvest in the baseline conservation condition scenario.

Commercial phosphorus fertilizer rate. The threshold for identifying proper phosphorus application rates was 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. The threshold is lower for phosphorus than for nitrogen because phosphorus is not lost through volatilization to the atmosphere and much less is lost through other pathways owing to strong bonding of phosphorus to soil particles.

For the no-practice scenario, the amount of commercial phosphorus fertilizer applied was increased to 1.57 times the harvest removal rate for the crop rotation. The ratio of 1.57 for the increased phosphorus rate was determined by the average rate-to-yield-removal ratio for crops with phosphorus applications exceeding 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. Multiple commercial phosphorus fertilizer applications were increased proportionately to meet the 1.57 threshold.

Manure application rate. For sites receiving manure, the appropriate manure application rate in tons per acre was identified on the basis of the total nitrogen application rate, including both manure and commercial nitrogen fertilizer. Thus, if the total for all applications of nitrogen (commercial fertilizer and manure) was less than or equal to 1.4 times removal at harvest for non-legume crops, the no-practice manure application rate was increased such that the combination of commercial fertilizer and manure applications resulted in a total rate of nitrogen application equal to 1.68 times harvest removal. Both commercial nitrogen fertilizer and the amount of manure were increased proportionately to reach the no-practice scenario rate. For small grain crops, the same approach was used using the criteria defined above for commercial nitrogen fertilizer. As done with commercial nitrogen fertilizer, the assessment was made separately for each crop in the rotation.

Any increase in phosphorus from manure added to meet the nitrogen criteria for the no-practice scenario was taken into account in setting the no-practice commercial phosphorus fertilizer application rate.

Thus, no adjustment was made to manure applied at rates below the P threshold of 1.1 in the no-practice scenario because the manure application rate was based on the nitrogen level in the manure.

Timing of application. Nutrients applied closest to the time when a plant needs them are the most efficiently utilized and least likely to be lost to the surrounding environment. All commercial fertilizer applications occurring within 3 weeks prior to planting, at planting, or within 60 days after planting were moved back to 3 weeks prior to planting for the no-practice scenario. For example, split applications that occur within 60 days after planting are moved to a single application 3 weeks before planting for the no-practice scenario.

Timing of manure applications was not adjusted in the no-practice scenario.

Method of application. Nutrient applications, including manure applications, that were incorporated or banded were changed to a surface broadcast application method for the no-practice scenario.

No-practice representation of pesticide management practices

Pesticide management for conservation purposes is a combination of three types of interrelated management activities:

1. A mix of soil erosion control practices that retain pesticide residues within the field boundaries.
2. Pesticide use and application practices that minimize the risk that pesticide residues pose to the surrounding environment.

3. Practice of Integrated Pest Management (IPM), including partial field applications and spot treatment.

The first activity is covered by the no-practice representation of structural practices and residue and tillage management. The second activity, for the most part, cannot be simulated in large-scale regional modeling because of the difficulty in assuring that any changes in the types of pesticides applied or in the method or timing of application would provide sufficient protection against pests to maintain crop yields.[15] Farmers, of course, have such options, and environmentally conscientious farmers make tradeoffs to reduce environmental risk. But without better information on the nature of the pest problem both at the field level and in the surrounding area, modelers have to resort to prescriptive and generalized approaches to simulate alternative pesticides and application techniques, which would inevitably be inappropriate for many, if not most, of the acres simulated.

The no-practice representation for pesticide management is therefore based on the third type of activity—IPM.

One of the choices for methods of pesticide application on the survey was "spot treatment." Typically, spot treatments apply to a small area within a field and are often treated using a hand-held sprayer. Spot treatment is an IPM practice, as it requires scouting to determine what part of the field to treat and avoids treatment of parts of the field that do not have the pest problem. The reported rate of application for spot treatments was the rate per acre treated. For the baseline simulation, it was assumed that all spot treatments covered 5 percent of the field. Since the APEX model run and associated acreage weight for the sample point represented the whole field, the application rate was adjusted downward to 5 percent of the per-acre rate reported for the baseline scenario. For the no-practice scenario, the pesticide application rate as originally reported was used, simulating treatment of the entire field rather than 5 percent of the field. In the Missouri River Basin, there were 61 sample points with spot treatments, representing 1.5 percent of the cropped acres.

Partial field treatments were simulated in a manner similar to spot treatments. Partial field treatments were determined using information reported in the survey on the percentage of the field that was treated. (Spot treatments, which are also partial field treatments, were treated separately as described above.) For the baseline scenario, application rates were reduced proportionately according to how much of the field was treated. For the no-practice scenario, the rate as reported in the survey was used, simulating treatment of the entire field. However, this adjustment for the no-practice scenario was only done for partial field treatments on less than one-third of the field, as larger partial field treatments could have been for reasons unrelated to IPM. About 1.4 percent of the cropped acres in the Missouri River Basin had partial field treatments of pesticides (49 samples).

The IPM indicator, described in the previous chapter, was used to adjust pesticide application methods and to increase the frequency of applications to represent "no IPM practice." For samples classified as having either high or moderate IPM use, all soil-incorporated pesticide applications in the baseline condition were changed to surface applications in the no-practice scenario. For high IPM cases, the first application event between planting and 30 days before harvest was replicated twice for each crop, 1 week and 2 weeks after its original application. For moderate IPM cases, the first application event was replicated one time for each crop, 1 week after its original application.

No-practice representation of land in long-term conserving cover

The no-practice representation of land in long-term conserving cover is cultivated cropping with no conservation practices in use. For each CRP sample point, a set of cropping simulations was developed to represent the probable mix of management that would be applied to the point if it were cropped. Cropped sample points were matched to each CRP sample point on the basis of slope, soil texture, soil hydrologic group, and geographic proximity. The cropped sample points that matched most closely were used to represent the cropped condition that would be expected at each CRP sample point if the field had not been enrolled in CRP. In most cases, seven "donor" points were used to represent the crops that were grown and the various management activities to represent crops and management for the CRP sample point "as if" the acres had not been enrolled in CRP. The crops and management activities of each donor crop sample were combined with the site and soil characteristics of the CRP point for the no-practice representation of land in long-term conserving cover.

[15] The APEX model can simulate pesticide applications, but it does not currently include a pest population model that would allow simulation of the effectiveness of pest management practices. Thus, the relative effectiveness of pesticide substitution or changes in other pest management practices cannot be evaluated.

Effects of Practices on Fate and Transport of Water

Water is a potent force that interacts with or drives almost all environmental processes acting within an agricultural production system. The hydrologic conditions prevalent in the Missouri River Basin are critical to understanding the estimates of sediment, nutrient, and pesticide loss presented in subsequent sections. The APEX model simulates hydrologic processes at the field scale—precipitation, irrigation, evapotranspiration, surface water runoff, infiltration, subsurface flows, and percolation beyond the bottom of the soil profile.

Baseline condition

Precipitation and irrigation are the sources of water for a field. Annual precipitation over the 47-year simulation averaged about 23 inches in this region—29 inches in the eastern portion of the basin and 18 inches in the western portion. (See figs. 7 and 8.)

Land in long-term conserving cover receives slightly more precipitation than cropped acres in the eastern portion of the basin but tends to be found in the drier parts of the western portion of the basin (table 13).

About 11.9 million cropped acres (14 percent) are irrigated in the Missouri River Basin, about two-thirds of which are in the western portion of the basin. As simulated in the models, irrigated crop acres receive about 12 inches of irrigation water per year, on average, in the eastern portion of the basin and 13 inches in the western portion (table 13).

Table 13. Water sources for cultivated cropland in model simulations of the Missouri River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Cropped acres		
Entire region (83.6 million acres)				
Non-irrigated acres (71.7 million acres)				
Average annual precipitation (inches)	22.8	22.8	0.0	0
Irrigated acres (11.9 million acres)				
Average annual precipitation (inches)	22.7	22.7	0.0	0
Average annual irrigation water applied (inches)	12.7	18.7	6.0	32
Eastern portion of region (36.36 million acres)				
Non-irrigated acres (32.42 million acres)				
Average annual precipitation (inches)	28.9	28.9	0.0	0
Irrigated acres (3.93 million acres)				
Average annual precipitation (inches)	27.7	27.7	0.0	0
Average annual irrigation water applied (inches)	11.8	19.8	7.9	40
Western portion of region (47.26 million acres)				
Non-irrigated acres (39.28 million acres)				
Average annual precipitation (inches)	17.8	17.8	0.0	0
Irrigated acres (7.98 million acres)				
Average annual precipitation (inches)	20.2	20.2	0.0	0
Average annual irrigation water applied (inches)	13.1	18.1	5.1	28
		Land in long-term conserving cover		
Entire region (11.2 million acres)				
Average annual precipitation (inches)	20.3	20.3	0.0	0
Average annual irrigation water applied (inches)*	0.0	1.3	1.3	100
Eastern portion of region (3.4 million acres)				
Average annual precipitation (inches)	30.1	30.1	0.0	0
Average annual irrigation water applied (inches)*	0.0	1.0	1.0	100
Western portion of region (7.7 million acres)				
Average annual precipitation (inches)	15.9	15.9	0.0	0
Average annual irrigation water applied (inches)*	0.0	1.4	1.4	100

*Land in long-term conserving cover was not irrigated, but some farming practices used to simulate a cropped condition to represent the no-practice scenario included irrigation. Values shown in the table for land in long-term conserving cover are averages over all acres, including non-irrigated acres.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 29 subregions.

Most of the water that leaves the field is lost through evaporation from the soil and plant surfaces and transpiration by plants (evapotranspiration) (table 14, fig. 15). Evapotranspiration is the dominant loss pathway for all cropped acres in this region. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) On average, about 73 percent of the water loss for cropped acres in this region is through evapotranspiration—65 percent in the eastern portion of the basin and 82 percent in the western portion. Model results indicate that evapotranspiration losses vary, however, according to soil characteristics and land cover; as shown in figure 16, evapotranspiration ranges from about 50 percent to more than 90 percent of the total amount of water that leaves the field.

Evapotranspiration for land in long-term conserving cover is similar to evapotranspiration for cropped acres except that it is slightly higher in the eastern portion of the basin and slightly lower in the western portion of the basin. The differences in evapotranspiration are consistent with the differences in precipitation between cropped acres and land in long-term conserving cover.

Subsurface flow pathways are the second largest source of water loss at an average of about 4.8 inches per year for cropped acres in the eastern portion of the basin and 1.8 inches in the western portion (table 14). Subsurface flow pathways include—

1. deep percolation to groundwater, including groundwater return flow to surface water,
2. subsurface flow that is intercepted by tile drains or drainage ditches, when present, and
3. lateral subsurface outflow or quick-return flow that emerges as surface water runoff, such as natural seeps.

Loss of water in subsurface flows averages about 14 percent of water loss for cropped acres in the eastern portion of the basin and 8 percent in the western portion. However, these percentages vary from zero percent to 50 percent, as shown in figure 16.

(In figures 15 and 16, the horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same sample point on another curve.)

Figure 15. Estimates of average annual water lost through three loss pathways for cropped acres in the Missouri River Basin, baseline conservation condition

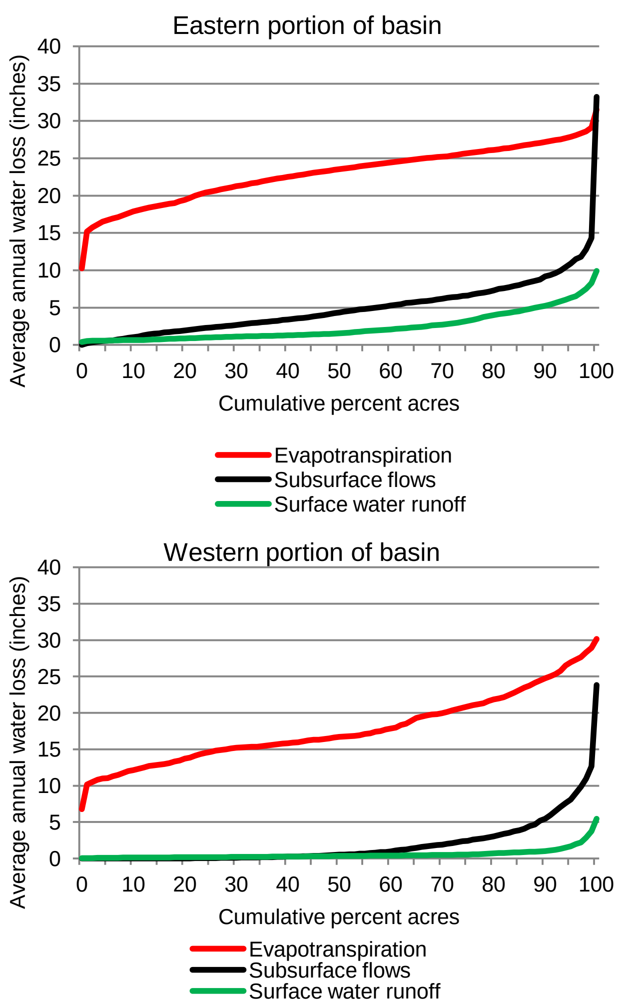
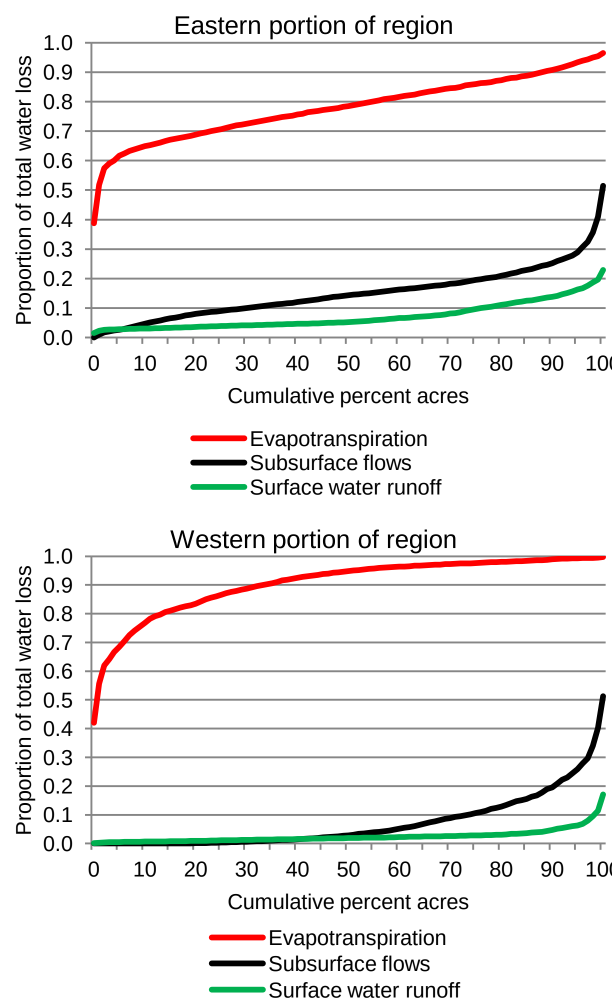


Figure 16. Proportion of water lost through three loss pathways for cropped acres in the Missouri River Basin, baseline conservation condition



Surface water runoff averages only about 5 percent of water loss for cropped acres, ranging from near zero to about 20 percent (fig. 16). Average surface water loss for cropped acres is about 2.4 inches per year in the eastern portion and 0.5 inch per year in the western portion (table 14). The amount of annual surface water runoff varies from zero to about 10 inches in the eastern portion of the basin and from zero to 5 inches in the western portion of the basin (fig. 15). Surface water runoff is higher for irrigated acres than for non-irrigated acres (table 14).

For land in long-term conserving cover, average annual surface water runoff averages less than half of the amount for cropped acres in the baseline within each portion of the region (table 14).

Table 14. Water loss pathways for cultivated cropland in the Missouri River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Cropped acres		
Entire region (83.6 million acres)				
Average annual evapotranspiration (inches)	20.0	20.2	0.2	1
Average annual surface water runoff (inches)	1.3	1.8	0.4	25
Irrigated acres	1.6	3.7	2.1	57
Non-irrigated acres	1.3	1.4	0.2	11
Average annual subsurface water flows (inches)*	3.1	2.7	-0.4	-15
Eastern portion of region (36.36 million acres)				
Average annual evapotranspiration (inches)	23.0	23.3	0.3	1
Average annual surface water runoff (inches)	2.4	2.9	0.5	18
Irrigated acres	2.7	4.7	2.0	42
Non-irrigated acres	2.3	2.6	0.3	12
Average annual subsurface water flows (inches)*	4.8	4.1	-0.7	-18
Western portion of region (47.26 million acres)				
Average annual evapotranspiration (inches)	17.7	17.9	0.1	1
Average annual surface water runoff (inches)	0.5	0.9	0.4	42
Irrigated acres	1.0	3.2	2.2	68
Non-irrigated acres	0.4	0.4	0.0	5
Average annual subsurface water flows (inches)*	1.8	1.7	-0.1	-8
		Land in long-term conserving cover		
Entire region (11.2 million acres)				
Average annual evapotranspiration (inches)	18.3	17.6	-0.6	-4
Average annual surface water runoff (inches)	0.5	1.5	1.0	69
Average annual subsurface water flows (inches)*	1.6	2.1	0.5	23
Eastern portion of region (3.4 million acres)				
Average annual evapotranspiration (inches)	24.5	22.6	-1.8	-8
Average annual surface water runoff (inches)	1.1	3.5	2.4	69
Average annual subsurface water flows (inches)*	4.7	4.6	-0.2	-4
Western portion of region (7.7 million acres)				
Average annual evapotranspiration (inches)	15.5	15.4	-0.1	-1
Average annual surface water runoff (inches)	0.2	0.6	0.4	70
Average annual subsurface water flows (inches)*	0.2	1.0	0.8	78

* Subsurface flow pathways include: (1) deep percolation to groundwater, including groundwater return flow; (2) subsurface flow intercepted by tile drains or drainage ditches; (3) lateral subsurface outflow; and (4) quick-return subsurface flow.
Note: The negative reductions shown for evapotranspiration and subsurface flows represent small average gains due to the use of conservation practices.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 29 subregions.

Tile Drainage

Tile drainage flow is included in the water loss category "subsurface water flows" in this report. (See table 14.) Other components of subsurface water flow include: 1) deep percolation to groundwater, including groundwater return flow to surface water, 2) lateral subsurface flows intercepted by surface drainage ditches, and 3) lateral subsurface outflow or quick-return flow that emerges as surface water runoff, such as natural seeps.

While the farmer survey provided information on whether or not the field with the CEAP sample point had tile drainage, tile drainage flow and loss of soluble nutrients in tile drainage water are not reported separately because other important information on the tile drainage characteristics were not covered in the survey. The missing information includes—

- the depth and spacing of the tile drainage field,
- the extent of the tile drainage network,
- the proportion of the field, or other fields, that benefited from the tile drainage system, and
- the extent to which overland flow and subsurface flow from surrounding areas enters through tile surface inlets.

Without this additional information, it is not possible to accurately separate out the various components of subsurface flow when tile drainage systems are present.

In the Missouri River basin, about 9 percent of the cropped acres have some portion of the field that is tile drained, according to the farmer survey. In the baseline, about 80 percent of the subsurface flow—as well as the soluble nutrients carried in the subsurface flow—were allocated by the physical process model (APEX) to tile drainage flow for these acres.

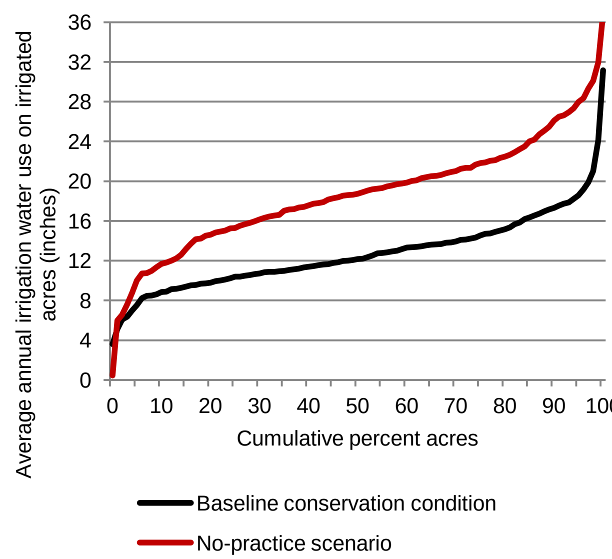
Effects of conservation practices

Cropped acres. Structural water erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil.[16] In addition, the less efficient irrigation technologies used to simulate the no-practice scenario result in reductions in irrigation water use for the baseline conservation condition.

Use of improved irrigation systems in the Missouri River Basin increases irrigation efficiency from 50 percent in the no-practice scenario to 69 percent in the baseline scenario. This change in efficiency represents an annual decreased need for irrigation water of 6 inches per year where irrigation is used (table 13). Irrigation water use savings were higher in the eastern portion of the basin (8 inches for irrigated acres, a 40-percent reduction relative to the baseline) than in the western portion (5 inches for irrigated acres, representing a 28-percent reduction). These water savings are shown graphically for all irrigated acres in the Missouri River Basin in figure 17.

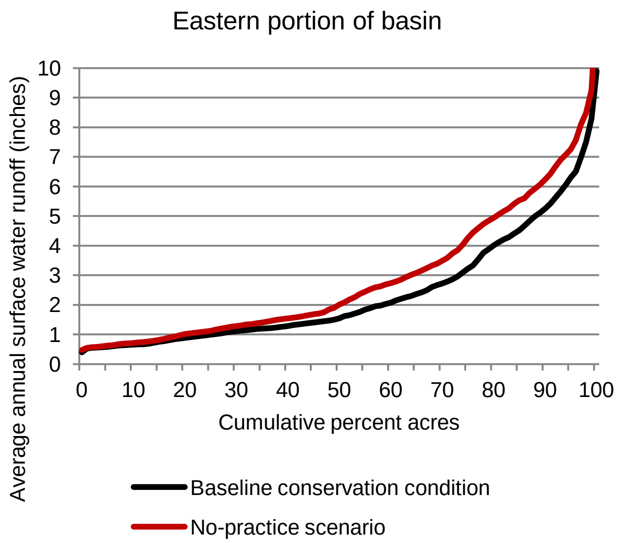
Model simulations indicate that conservation practices have reduced surface water runoff in the region by about 0.4 inch per year averaged over all acres, representing a 25-percent reduction (table 14, fig. 18). The per-acre reduction was about the same in the eastern portion of the basin as in the western portion, but the percent reduction was much higher in the western portion. Most of these reductions in surface water runoff occur for irrigated acres (table 14, fig. 19). For the entire region, conservation practices reduce surface water runoff by 2.1 inches per year, on average, for irrigated acres, compared to only 0.2 inch per year for nonirrigated acres.

Figure 17. Estimates of average annual irrigation water use for irrigated crop acres in the Missouri River Basin



[16] Model simulations did not include increased infiltration for some structural practices—model parameter settings conservatively prevented infiltration of run-on water and its dissolved contaminants in conservation buffers including field borders, filter strips and riparian forest buffers.

Figure 18. Estimates of average annual surface water runoff for cropped acres in the Missouri River Basin



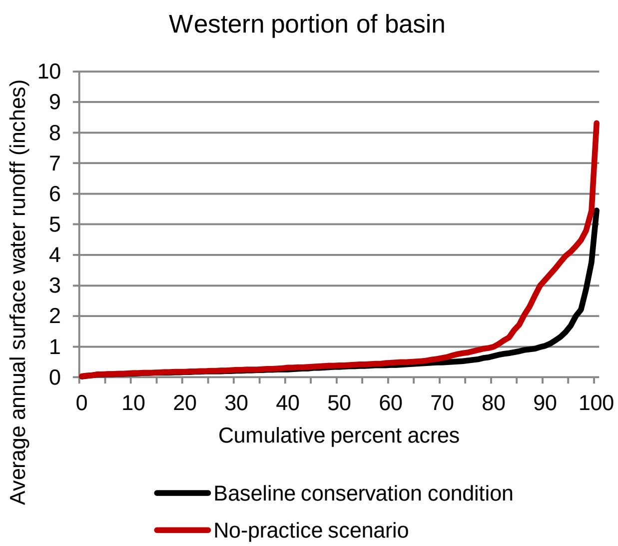
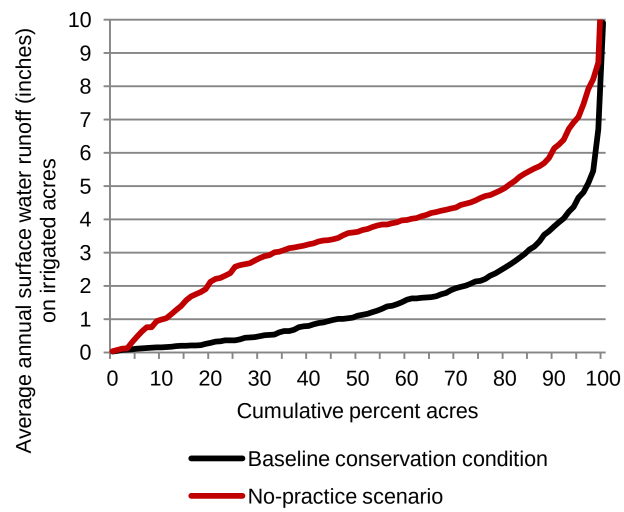


Figure 19. Estimates of average annual surface water runoff for irrigated crop acres in the Missouri River Basin



Reductions in surface water runoff due to conservation practices range from less than zero[17] to above 4 inches per year for cropped acres in the region (fig. 20). The variability in reductions due to practices reflects different levels of conservation treatment as well as differences in precipitation and inherent differences among acres for water to run off.

Subsurface flows, on the other hand, increase on most acres due to the use of conservation practices and decrease a small amount on other acres. The re-routing of surface water to subsurface flows is shown graphically in figures 21 and 22 for cropped acres. The no-practice scenario curve in figure 21 shows what the distribution of subsurface flows would be if there were no conservation practices in use—amounts generally less than amounts in the baseline conservation condition.

For all cropped acres in the region, conservation practice use increases the volume of subsurface flows by an average of 0.4 inch per year, with higher increases in the eastern portion of the basin and lower increases in the western portion (table 14, fig. 22). As shown in figure 22, conservation practice use produces reductions in subsurface water flows for some acres (shown as negative gains in the figure). For other acres, subsurface water flows have negligible gains, especially in the western portion of the basin. Gains in volume of subsurface flows range up to 3 inches per year for the remaining acres.

Conservation practices has little effect on average evapotranspiration for cropped acres (table 14).

[17] About 1 percent of cropped acres have less surface water runoff in the no-practice scenario than the baseline, resulting in negative reductions. These gains in surface water runoff when conservation practices are applied can occur on soils with low to moderate potential for runoff when: (1) excessive nutrient application rates in the no-practice scenario produces more biomass, lowering soil moisture and thus reducing runoff, or (2) tillage of the surface soil in the no-practice scenario reduces surface compaction and crusting, producing temporary surface roughness that in turn reduces runoff.

Figure 20. Estimates of average annual reduction in surface water runoff due to the use of conservation practices on cropped acres in the Missouri River Basin

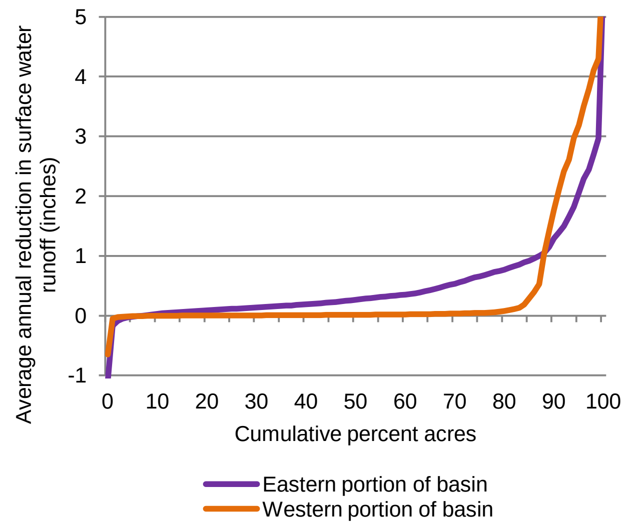


Figure 21. Estimates of average annual subsurface flows for cropped acres in the Missouri River Basin

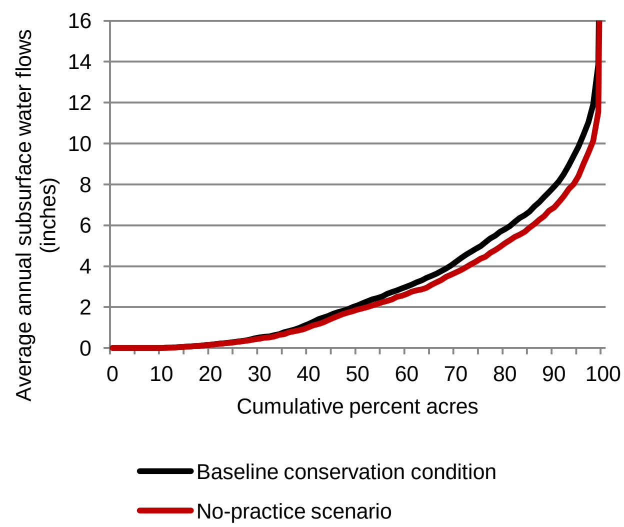
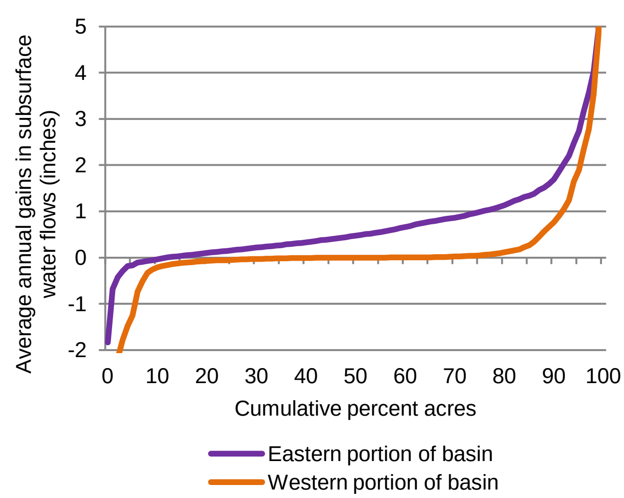


Figure 22. Estimates of average annual gain in subsurface flows due to the use of conservation practices on cropped acres in the Missouri River Basin



Land in long-term conserving cover. At 11.2 million acres, land in long-term conserving cover is an important part of the agricultural landscape in the Missouri River Basin. The benefits of this conservation "practice" were estimated by simulating crop production (without use of conservation practices) on each sample point from the NRI that represented acres enrolled in the Conservation Reserve Program General Sign-up. The soils characteristics and weather used in the simulation were taken from the NRI sample point and combined with farming activities, including crops grown, from similar acres in the CEAP dataset for cropped acres, as described earlier in this chapter.

Reductions in surface water runoff due to conversion to long-term conserving cover average 1.0 inch per year in this region, representing an average annual reduction of 69 percent (table 14). As shown in figure 23, however, per-acre reductions vary from very small amounts in the drier western portion of the basin to reductions of 5 inches or more on acres in the eastern portion.

Most acres in long-term conserving cover reduce the volume of water lost from the field in subsurface flow pathways, as indicated in figure 24 by negative gains. Conversion of cultivated cropland to long-term conserving cover in the eastern portion of the region results in an average gain of 0.2 inch per year (table 14), with positive gains for about half of the acres that range to more than 5 inches per year (fig. 24). In the western portion of the region, however, few acres have significant gains in subsurface flows. The average reduction in subsurface flows in the western portion of the basin is 0.8 inch per year due to conversion of cultivated cropland to long-term conserving cover. Figure 24 also shows, however, that long-term conserving cover for the majority of acres in the western portion of the basin has little effect on subsurface flows compared to a cropped condition without use of conservation practices.

Figure 23. Estimates of average annual reduction in surface water runoff due to conversion to long-term conserving cover in the Missouri River Basin

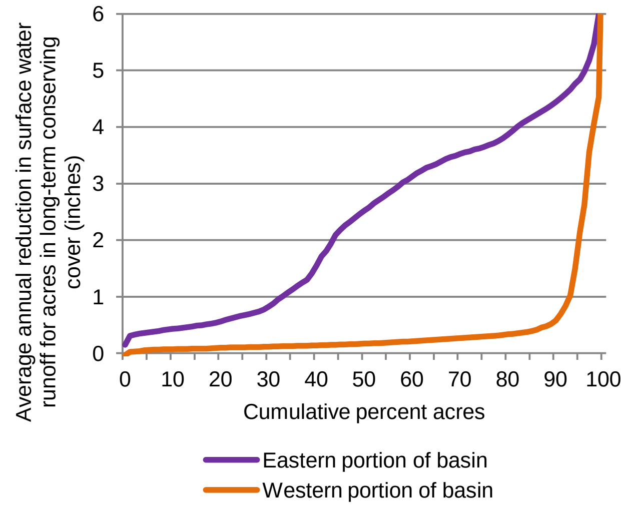
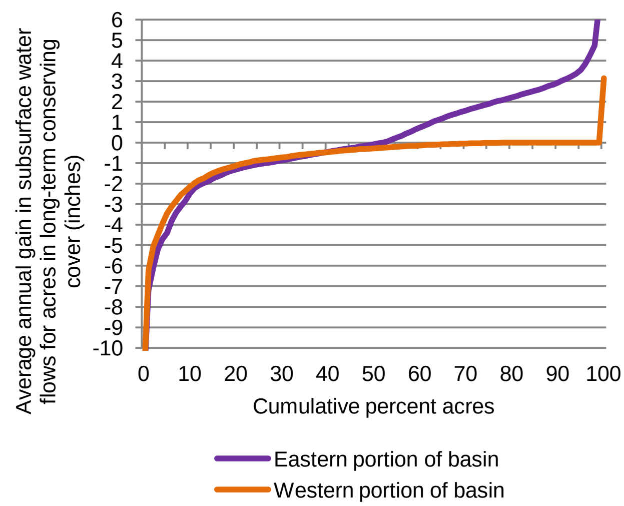


Figure 24. Estimates of average annual gain in subsurface flows due to conversion to long-term conserving cover in the Missouri River Basin



Cumulative Distributions Show How Effects of Conservation Practices Vary Throughout the Region

The design of this study provides the opportunity to examine not only the overall mean value for a given outcome, but also the entire distribution of outcomes. This is possible because outcomes are estimated for each of the 3,916 sample points used to represent cropped acres in the Missouri River Basin and for each of the 4,281 sample points used to represent land in long-term conserving cover. Cumulative distributions show the full set of estimates and thus demonstrate how conditions and the effects of conservation practices vary throughout the region.

Cumulative distributions shown in this report are plots of the value for each percentile. In figure 18, for example, the curve for average annual surface water runoff for the baseline conservation condition, eastern portion of the basin, consists of each of the percentiles of the distribution of 2,227 surface water runoff estimates for the eastern portion of the basin, weighted by the acres associated with each sample point. The 10^{th} percentile for the baseline conservation condition is 0.65 inch per year, indicating that 10 percent of the acres have 0.65 inch or less of surface water runoff, on average. Similarly, the same curve shows that 25 percent of the acres have surface water runoff less than 1.0 inch per year. The 50^{th} percentile—the median—is 1.5 inches per year, compared to the mean value of 2.4 inches per year from table 14. At the high end of the distribution, 90 percent of the acres in this region have surface water runoff less than 5.3 inches per year; and conversely, 10 percent of the acres have surface water runoff greater than 5.3 inches per year.

Thus, the distributions show the full range of outcomes for cultivated cropland acres in the Missouri River Basin . The full range of outcomes for the baseline condition is compared to that for the no-practice scenario in figure 18 to illustrate the extent to which conservation practices reduce surface water runoff throughout the region.

Figure 20 shows the effects of conservation practices on surface water runoff using the distribution of the *reduction* in surface water runoff, calculated as the outcome for the no-practice scenario minus the outcome for the baseline conservation condition at each of the sample point. The distribution for the eastern portion of the basin shows that, while the mean reduction is 0.5 inch per year, 12 percent of the acres have reductions due to conservation practices greater than one inch per year and about 2 percent of the acres actually have small increases in surface water runoff (i.e., negative reductions) as a result of conservation practice use.

Effects of Practices on Wind Erosion

Wind velocity, tillage, vegetative cover, and the texture and structure of the soil are primary determinants of wind erosion. Wind erosion removes the most fertile parts of the soil such as the lighter, less dense soil constituents including organic matter, clays, and silts. Wind erosion occurs when the soil is unprotected and wind velocity exceeds about 13 miles per hour near the surface. Wind erosion is estimated in APEX using the Wind Erosion Continuous Simulation (WECS) model. The estimated wind erosion rate is the amount of eroded material leaving the downwind edge of the field.

Wind erosion is a significant resource concern for some cropped acres in the Missouri River Basin. A concern of crop producers with wind erosion is crop damage to young seedlings exposed to windblown material. Wind erosion rates as low as 0.5 ton per acre have caused physical damage to young seedlings. Wind erosion can also deposit sediment rich in nutrients into adjacent ditches and surface drainage systems, where it is then transported to water bodies with runoff. Wind erosion rates greater than 2 tons per acre per year can result in significant losses of soil and associated contaminants over time. Wind erosion rates greater than 4 tons per acre can result in excessive soil loss annually and can also have adverse effects on human health.

Baseline condition

For all cropped acres, model simulations show that the average annual rate of wind erosion is 1.13 tons per acre (table 15). Wind erosion is much higher in the western portion of the basin, averaging 1.64 tons per acre. Wind erosion in the eastern portion of the region averages 0.46 ton per acre, which is still high enough to be of concern in some years.

Figure 25 shows the annual variability in wind erosion for the region. During some years and for some acres, wind erosion rates can be very high. Wind erosion rates exceed 4 tons per acre in at least some years for 12 percent of the acres in the region, and exceed 2 tons per acre in some years for about 20 percent of the acres. Figure 25 also shows, however, that the majority of acres in the region do not have excessive wind erosion; about 68 percent of cropped acres have wind erosion rates less than 1 ton per acre in all years.

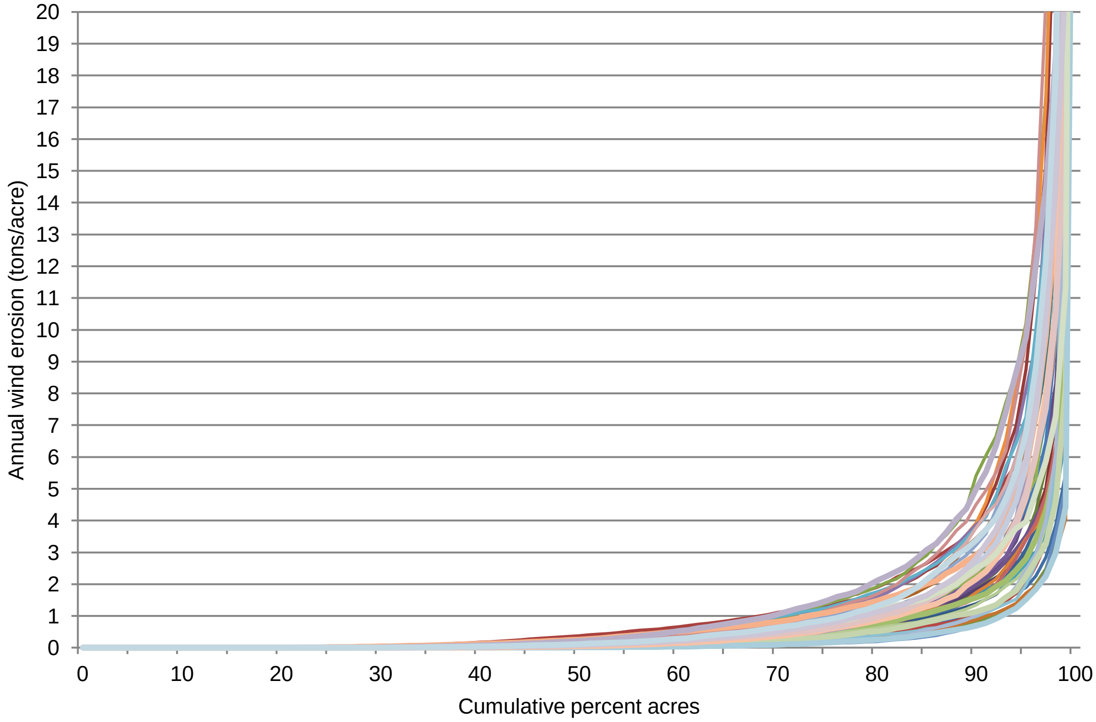
Wind erosion on land in long-term conserving cover is negligible (table 15).

Table 15. Average annual wind erosion (tons/acre) for cultivated cropland in the Missouri River Basin

	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Cropped acres		
Entire region (83.6 million acres)	1.13	2.66	1.53	58
Eastern portion of region (36.36 million acres)	0.46	1.34	0.88	66
Western portion of region (47.26 million acres)	1.64	3.68	2.04	55
		Land in long-term conserving cover		
Entire region (11.2 million acres)	<0.01	4.11	4.11	100
Eastern portion of region (3.4 million acres)	<0.01	1.62	1.62	100
Western portion of region (7.7 million acres)	<0.01	5.23	5.23	100

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 29 subregions.

Figure 25. Distribution of annual wind erosion rate for each year of the 47-year model simulation, Missouri River Basin



Note: This figure shows how annual wind erosion (tons per acre per year) varies within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual wind erosion varies over the region in that year, starting with the acres with the lowest rates and increasing to the acres with the highest rates. The family of curves shows how annual wind erosion rates vary from year to year.

Costs of Excessive Wind Erosion

Wind erosion represents a major natural resource problem in the western United States. Of the estimated annual two billion tons of cropland soil loss by wind, approximately 88 percent occurs in the Western states. During a windstorm, the very fine windblown soil material becomes suspended in the atmosphere and may travel many miles before being deposited back to the surface. Windblown sediment is often deposited in drainage ditches, where it is then easily transported into rivers and streams with surface water runoff. Windblown material originating from cropland is generally rich in nutrients and can contain pesticides and other contaminants.

Programs and mitigating practices are traditionally designed and paid for on the basis of losses in soil productivity, crop quality and yield, and other on-farm economic impacts. But the full costs of wind erosion also include offsite damages. The two most obvious offsite impacts relate to maintenance of roadside ditches and reduced visibility on highways, sometimes resulting in accidents and fatalities. Other impacts include human health issues associated with impaired air quality and costs related to clean up, repair and replacement of equipment and facilities (Huszar 1989). In a study of offsite costs of wind erosion in New Mexico, offsite costs were estimated to average over $400 million per year, dwarfing the $10 million per year onsite damages estimated by other studies (Davis 1989). The annual offsite wind erosion costs for all the western states are estimated at between $3.76 and $12.08 billion (Huszar 1989).

Effects of conservation practices

Farmers address wind erosion using conservation practices designed to enhance the soil's ability to resist and reduce the wind velocity near the soil surface. Properly planned and applied residue management reduces wind erosion by leaving more organic material on the soil surface, which in turn helps preserve soil aggregate stability and promotes further aggregation. Physical barriers such as windbreaks or shelterbelts, herbaceous wind barriers or windbreaks, cross wind trap strips, or ridges constructed perpendicular to the prevailing wind direction also reduce the intensity of wind energy at the surface. Row direction or arrangement, surface roughening, and stripcropping also lessen the wind's energy.

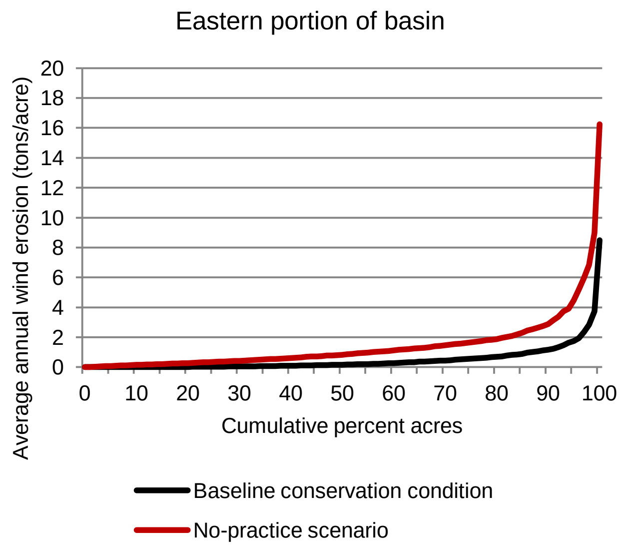
Structural practices for wind erosion control are in use on 10 percent of the cropped acres in the Missouri River Basin. Other practices common in the region, such as residue and tillage management, reduced tillage, and various water erosion control practices, are also effective in reducing wind erosion.

Model simulations indicate that conservation practices have reduced the average wind erosion rate for the region by 58 percent (table 15, fig. 26). Reductions in wind erosion on cropped acres are much higher in the western portion of the basin than in the eastern portion, as shown in figure 27. On average, conservation practices have reduced wind erosion by 2.04 tons per acre in the western portion of the basin and reduced wind erosion by 0.88 ton per acre in the eastern portion. Figure 27 shows, however, that reductions in wind erosion due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil.[18]

Wind erosion on land in long-term conserving cover has essentially been eliminated, representing per-acre reductions averaging 4.11 tons per acre per year compared to a cropped condition for those acres (table 15).

[18] For a small number of acres (1 percent of cropped acres in the eastern portion and 3 percent in the western portion), wind erosion was slightly higher in the baseline condition than in the no-practice scenario, resulting in small negative reductions shown in figure 27. This condition can occur on some acres because of the higher fertilization rates used to simulate the no-practice scenario, which can result in more vegetative cover protecting the soil from the forces of the wind.

Figure 26. Estimates of average annual wind erosion for cropped acres in the Missouri River Basin



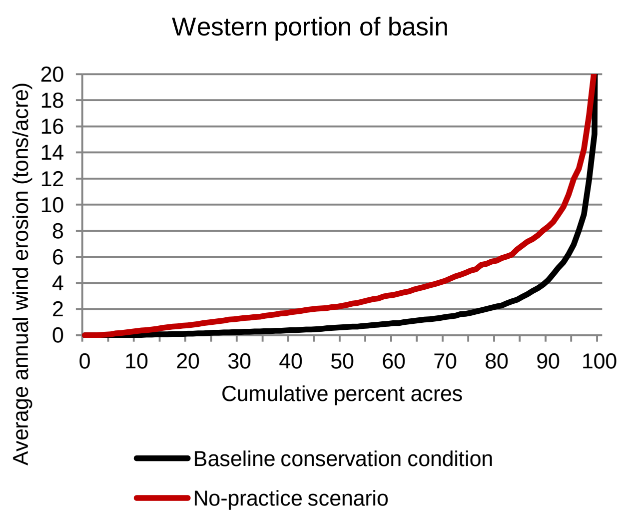
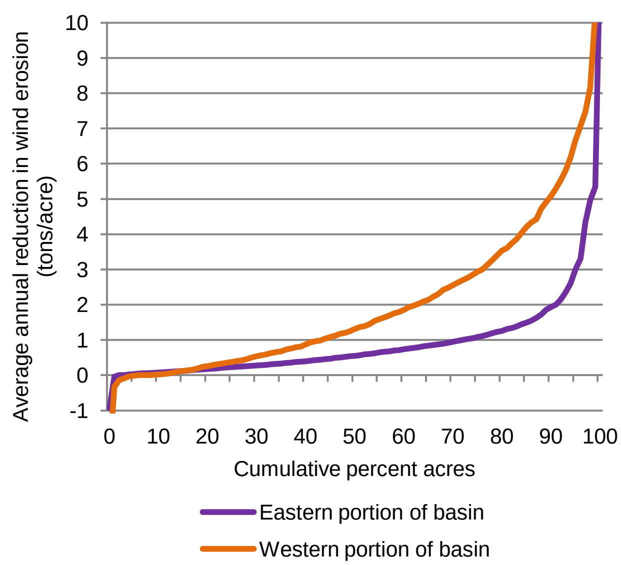


Figure 27. Estimates of average annual reduction in wind erosion due to the use of conservation practices on cropped acres in the Missouri River Basin



Effects of Practices on Water Erosion and Sediment Loss

Sheet and rill erosion

Forms of water erosion include sheet and rill, ephemeral gully, classical gully and streambank. Each type is associated with the progressive concentration of runoff water into channels leading downslope. The first stage is sheet and rill erosion, which can be modeled using the Universal Soil Loss Equation (USLE). Sheet and rill erosion is the detachment and movement of soil particles within the field that occurs during rainfall events. Controlling sheet and rill erosion is important for sustaining soil productivity and preventing soil from leaving the field.

Model simulations show that sheet and rill erosion on cropped acres in the Missouri River Basin averages about 0.31 ton per acre per year (table 16). Sheet and rill erosion rates are higher in the eastern portion of the basin, averaging 0.61 ton per acre per year, than in the western portion, where sheet and rill erosion rates average only 0.08 ton per acre.

Model simulation results also show that conservation practices have reduced sheet and rill erosion on cropped acres in the Missouri River Basin by an average of 0.43 ton per acre per year, representing a 58-percent reduction on average (table 16). Percent reductions were about the same in the eastern and western portions of the basin, but the magnitude of the reduction in sheet and rill erosion is much higher in the eastern portion.

For land in long-term conserving cover, sheet and rill erosion has been reduced from 1.27 tons per acre per year if cropped without conservation practices to 0.02 ton per acre (table 16), on average.

Sediment loss from water erosion

Soil erosion and sedimentation are separate but interrelated resource concerns. Sedimentation is that portion of the eroded material that settles out in areas onsite or offsite. Sediment loss, as estimated in this study, includes the portion of the sheet and rill eroded material that is transported beyond the edge of the field and settles offsite as well as some sediment that originates from gully erosion processes. Sediment is composed of detached and transported soil minerals, organic matter, plant and animal residues, and associated chemical and biological compounds. Edge-of-field conservation practices are designed to filter out a portion of the material and reduce sediment loss.

For this study, the APEX model was set up to estimate sediment loss using a modified version of MUSLE, called MUST (not MUSS, as was mistakenly reported in the CEAP reports on the Chesapeake Bay, the Great Lakes, and the Ohio-Tennessee River Basins).[19] The model variant called MUST uses an internal sediment delivery ratio to estimate the amount of eroded soil that actually leaves the boundaries of the field. A large percentage of the eroded material is redistributed and deposited within the field or trapped by buffers and other conservation practices and does not leave the boundary of the field, which is taken into account in the sediment delivery calculation. The estimate also includes some gully erosion and some ephemeral gully erosion. For this reason, sediment loss rates can exceed sheet and rill erosion rates.

Estimates of sediment loss from water erosion do not include wind-eroded material that is subsequently deposited along field borders or in ditches and transported as sediment with rainfall and runoff events. The current state of water erosion modeling does not include sediment displaced from the field by wind. (Wind eroded material incorporated into the soil with tillage or biological activity prior to a runoff event would be included, however.) Wind-eroded material can be an important source of sediment delivered to rivers and streams in this region.

Baseline condition for cropped acres. The average annual sediment loss for cropped acres in the Missouri River Basin is low compared to other regions of the country, averaging only 0.26 ton per acre per year for the entire region, according to the model simulation (table 16). Sediment loss is highest in the eastern portion of the basin, averaging 0.50 ton per acre, compared to an average of 0.08 ton per acre in the western portion.

On an annual basis, however, sediment loss can be high for some acres. Figure 28 shows that, with the conservation practices currently in use in the Missouri River Basin, annual sediment loss can exceed 2 tons per acre for about 13 percent of the acres in one or more years.[20] Figure 28 also shows that nearly 80 percent of cropped acres would have low levels of sediment loss (less than 1 ton per acre) under all conditions, including years with high precipitation.

Soil loss due to water erosion is much lower than soil loss due to wind erosion in this region, as can be seen by comparing figure 28 to figure 25. (Both figures are drawn to the same scale for comparison.) The comparison also shows that, for both wind erosion and water erosion, erosion concerns are low or negligible for most cropped acres in the region, even during years with high or low precipitation. Acres with high soil loss are restricted to a minority of acres within the region that have the highest inherent vulnerability for erosion and have inadequate soil erosion control practices in place.

[19] APEX provides a variety of options for modeling erosion and sedimentation, including USLE, RUSLE, MUSS, MUSLE, and MUST. MUST is the most appropriate choice for simulation of sediment loss for small areas (less than 1 hectare, for example).

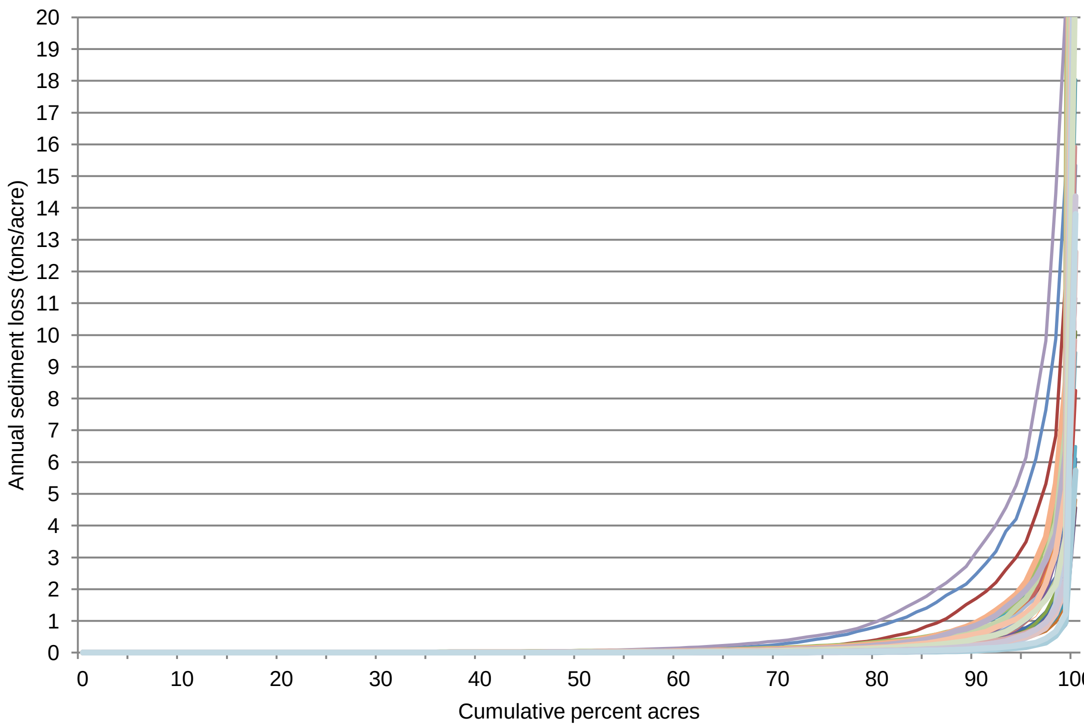
[20] Sediment loss for three of the 47 years stands out by having much higher losses for acres with significant levels of loss. The three years are, in order from the highest to lowest: 1993, 1984, and 1973. Two of those years—1993 and 1973—are among the years with the highest annual precipitation over the 47 years used in the model simulation for both the eastern and western portions of the basin.

Table 16. Field-level effects of conservation practices on erosion and sediment loss for cultivated cropland in the Missouri River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Cropped acres			
Entire region (83.6 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.31	0.74	0.43	58
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.26	0.98	0.72	73
Eastern portion of region (36.36 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.61	1.51	0.90	59
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.50	1.76	1.26	72
Western portion of region (47.26 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.08	0.15	0.07	47
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.08	0.38	0.30	79
	Land in long-term conserving cover			
Entire region (11.2 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.03	0.97	0.95	97
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.02	1.27	1.26	99
Eastern portion of region (3.4 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.08	2.86	2.78	97
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.04	3.42	3.39	99
Western portion of region (7.7 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.00	0.13	0.13	97
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.01	0.31	0.31	98

* Estimated using the Revised Universal Soil Loss Equation.
**Estimated using MUSS, which includes some sediment from gully erosion. See text.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 29 subregions.

Figure 28. Distribution of annual sediment loss for each year of the 47-year model simulation, Missouri River Basin



Note: This figure shows how annual sediment loss (tons per acre per year) varies within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual sediment loss varies over the region in that year, starting with the acres with the lowest sediment loss and increasing to the acres with the highest sediment loss. The family of curves shows how annual sediment loss varies from year to year.

Figure 29. Estimates of average annual sediment loss for cropped acres in the Missouri River Basin

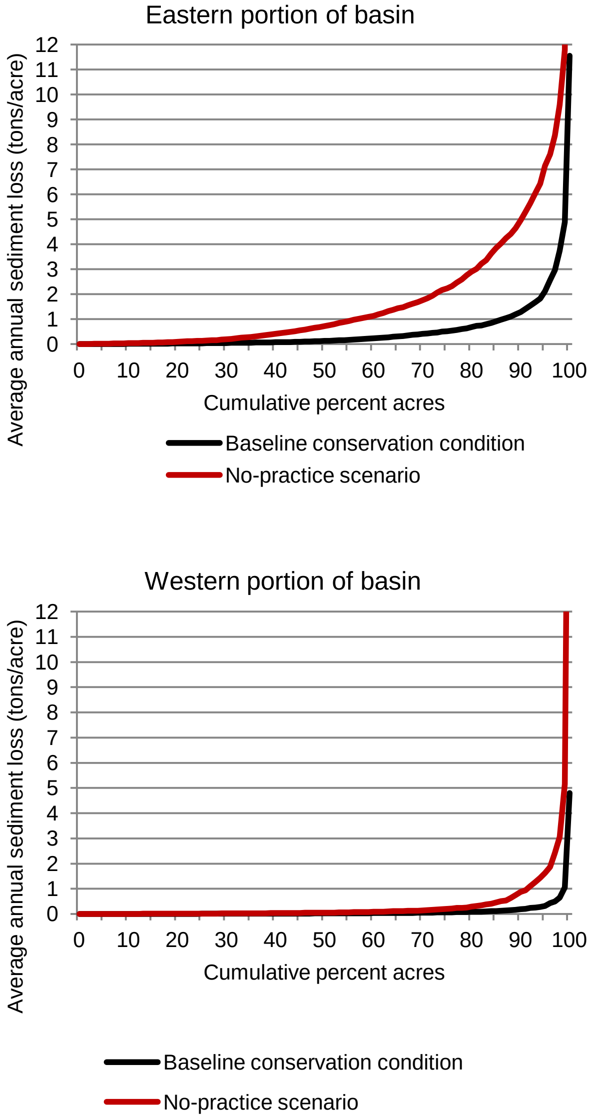
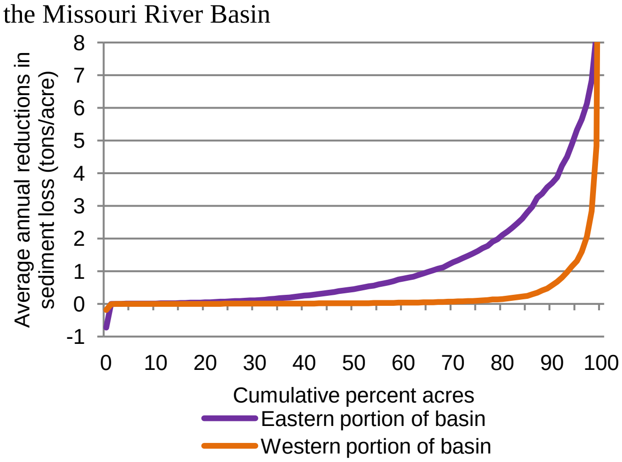


Figure 30. Estimates of average annual reduction in sediment loss due to the use of conservation practices on cropped acres in the Missouri River Basin



Note: About 1 percent of the acres had less sediment loss in the no-practice scenario than the baseline conservation condition, resulting from the increase is surface water runoff on some acres due to conservation practices. (See figure 20.)

Effects of conservation practices on cropped acres. Without conservation practices, sediment loss would be a significant issue in the eastern portion of the basin, as shown in figure 29. Model simulations indicate that the use of conservation practices in the Missouri River Basin has reduced average annual sediment loss from water erosion in the eastern portion of the basin by an average of 1.26 tons per acre per year, representing a 72-percent reduction. Conservation practices were also effective in reducing sediment loss in the western portion of the basin, where sediment loss was reduced 79 percent, on average.

Reductions in sediment loss due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil. Figures 29 and 30 show that significant reductions in the western portion of the basin are restricted to the 10-15 percent of cropped acres with the highest vulnerability to sediment loss. In the eastern portion, reductions in sediment loss were greater than 1 ton per acre for about 35 percent of cropped acres (figure 30).

Land in long-term conserving cover. Acres in long-term conserving cover have very little erosion or sediment loss, and thus show nearly 100-percent reductions when compared to a cropped condition (table 16). If these 11.2 million acres were still being cropped without any conservation practices, sediment loss would average about 1.27 tons per acre per year for these acres for the entire region—3.42 tons per acre in the eastern portion of the basin and 0.31 ton per acre in the western portion (table 16).

Effects of Practices on Soil Organic Carbon

The landscape and climate in the Missouri River Basin is conducive to maintaining and enhancing soil organic carbon in the eastern portion of the basin but less so in the western portion.

Soils are more fertile and precipitation is higher in the eastern portion of the basin than in the western portion. Soil organic carbon levels in the eastern portion of the basin are relatively high—similar to those in the Upper Mississippi River Basin. The eastern portion is in the same Land Resource Region (Central Feed Grains and Livestock) as most of the Upper Mississippi River Basin and is characterized by deep soils developed under tall grass prairie vegetation (loamy soils). As a result, corn and soybean rotations tend to dominate the production systems in this region.

The western portion of the basin occurs primarily in the Central, Northern, and Western Great Plains Land Resource regions and is dominated by wheat and other small grain production. It receives 11 inches per year less rainfall than the eastern portion, on average. These dry conditions strongly influence the amount of biomass production potential. The soils in the western portion developed under short and mid-grass prairies and are generally shallower than in the eastern portion. The drier climate and lower biomass production potential makes it more difficult for the residue management cropping systems in the western portion to accumulate carbon. The drier climate also slows biological degradation, however, and soil organic carbon can accumulate in soils when disturbance by tillage is minimal.

In this study, estimation of soil organic carbon change is based on beginning soil characteristics that reflect the effects of years of traditional conventional tillage practices and older, lower yielding crop varieties. These effects generally resulted in soils with organic carbon levels at or near their low steady state. Modern high-yielding crop varieties with and without the adoption of conservation tillage tend to readily improve the status of carbon in many soils, especially those with beginning stocks far less than the steady state representation of the present management. Beginning the simulations at a lower steady state for carbon allows for a more equitable comparison of conservation practices, particularly conservation tillage. Because of this, model estimates of soil organic carbon change may be somewhat larger than shown in other studies. Nevertheless, model estimates obtained in this study fall within the expected range for the continuum of adoption of new crop genetics and tillage practices.

Baseline condition for cropped acres

Model simulation shows that for the baseline conservation condition the average annual soil organic carbon change is a gain of about 139 pounds per acre per year for the eastern portion of the basin and a loss of about 15 pounds per acre per year for the western portion (table 17). About 84 percent of cropped acres in the eastern portion of the basin are gaining soil organic carbon (fig. 31). About 42 percent of cropped acres in the western portion of the basin are gaining soil organic carbon.

These estimates account for losses of carbon with sediment removed from the field by wind and water erosion. Loss of soil organic carbon due to wind and water erosion averages about 164 pounds per acre per year for the baseline conservation condition in the eastern portion of the basin and 110 per acre per year in the western portion (table 17).

Cropped acres that are gaining soil organic carbon every year provide soil quality benefits that enhance production and reduce the potential for sediment, nutrient, and pesticide losses. Soil organic carbon improves the soil's ability to function with respect to nutrient cycling, improves water holding capacity, and reduces erodibility through enhanced soil aggregate stability.

Given the challenging nature of the inherent conditions in some parts of this region, maintenance of soil organic carbon is also an important benchmark. Cropping systems can be considered to be maintaining soil organic carbon if average annual losses do not exceed 100 pounds per acre per year; this rate of change is typically too small to detect via typical soil sampling over a 20-year period. Applying this criterion, about 35 percent of the acres in the western portion of the basin and 12 percent in the eastern portion would be considered to be maintaining (but not enhancing) soil organic carbon. A total of 77 percent of the acres in the western portion of the basin and 96 percent in the eastern portion would be either maintaining or enhancing soil organic carbon (fig. 31).

Effects of conservation practices on cropped acres

Without conservation practices, the annual change in soil organic carbon would be an average loss of 12 pounds per acre per year for the entire region, compared to an average gain of 52 pounds per acre for the baseline (table 17). Thus, conservation practices in the region have resulted in an average annual gain in soil organic carbon of 64 pounds per acre per year on cropped acres. Average gains are higher in the eastern portion of the basin (74 pounds per acre per year) than in the western portion (58 pounds per acre per year).

Average annual change in soil organic carbon varies considerably among acres in the region, as shown in figure 32, depending on the extent to which residue and nutrient management is used as well as the soil's potential to sequester carbon.

For the entire region, the 60 percent of acres gaining soil organic carbon have an average annual gain of 152 pounds per acre per year in the baseline conservation condition. If conservation practices were not in use, only 46 percent of the acres would be gaining soil organic carbon and the annual rate of gain would be about 128 pounds per acre per year on those acres.

Some of the increased gain in soil organic carbon due to conservation practices is the result of soil erosion control—keeping soil organic carbon on the field promotes soil quality. Residues are not only key in increasing soil organic carbon, they are also vital as physical protection against erosion

losses. If conservation practices were not in use, loss of soil organic carbon due to wind and water erosion would average 202 pounds per acre per year over the entire region, compared to 133 pounds per acre per year with conservation practices (table 17). This represents an average reduction due to practices of 34 percent—30 percent in the eastern portion of the basin and 38 percent in the western portion.

For air quality concerns, the analysis centers on the decrease in carbon dioxide emissions. Soils gaining carbon are obviously diminishing emissions, but so are soils that continue to lose carbon but at a slower rate. For all cropped acres, the gain in soil organic carbon of 65 pounds per acre per year due to conservation practice use is equivalent to a carbon dioxide emission reduction of 9.9 million U.S. tons of carbon dioxide for the Missouri River Basin.

Table 17. Field-level effects of conservation practices on soil organic carbon for cultivated cropland in the Missouri River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Cropped acres		
Entire region (83.6 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	133	202	69	34%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	52	-12	65*	--
Eastern portion of region (36.36 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	164	236	72	30%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	139	66	74*	--
Western portion of region (47.26 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	110	176	67	38%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-15	-73	58*	--
		Land in long-term conserving cover		
Entire region (11.2 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	14	235	221	94%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	85	-107	192*	--
Eastern portion of region (3.4 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	34	328	294	90%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	175	-41	216*	--
Western portion of region (7.7 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	5	194	188	97%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	44	-136	181*	--

***** Gain in soil organic carbon due to conservation practices.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 29 subregions.

Figure 31. Estimates of average annual change in soil organic carbon for cropped acres in the Missouri River Basin

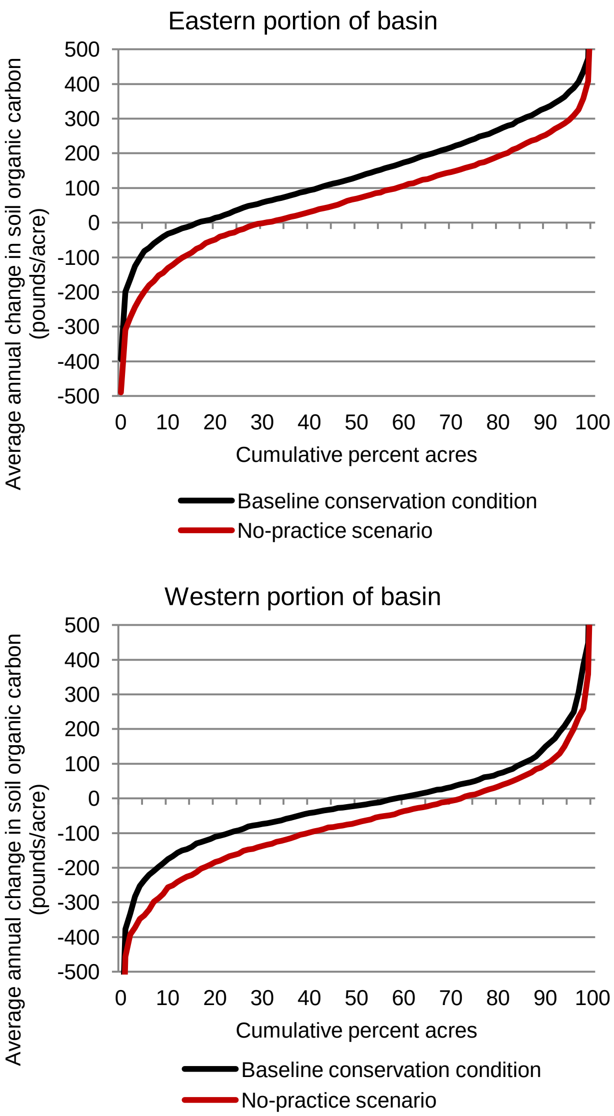
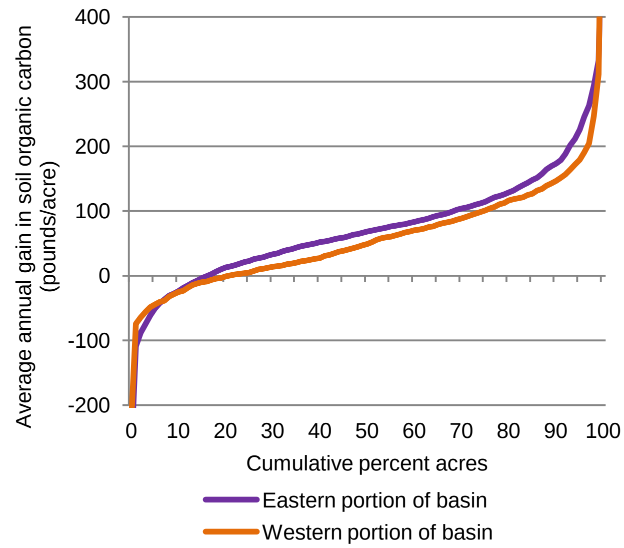


Figure 32. Estimates of average annual gain in soil organic carbon due to the use of conservation practices on cropped acres in the Missouri River Basin



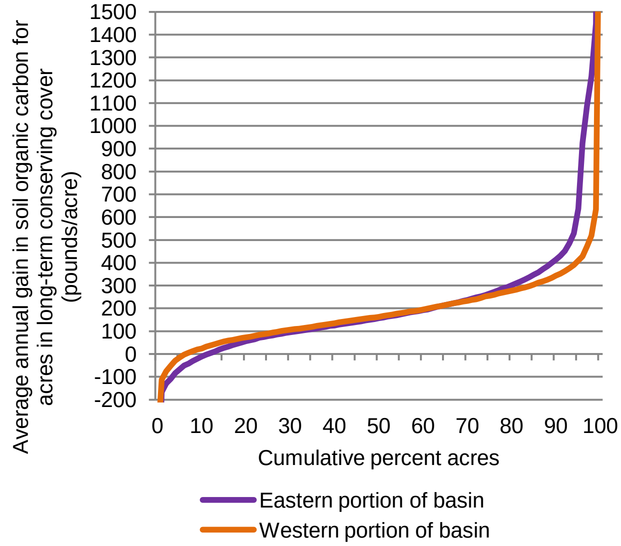
Note: Some acres in each portion of the basin lose soil organic carbon due to use of conservation practices, indicated in the figure by negative gains—16 percent and 20 percent of cropped acres in the eastern and western portions, respectively. For these acres, soil organic carbon increases in the no-practice scenario are higher than in the baseline conservation condition because of the higher fertilization rates, including manure application rates, used in the no-practice scenario to simulate the effects of nutrient management practices.

Land in long-term conserving cover

For land in long-term conserving cover, the annual change in soil organic carbon for the baseline conservation condition averages 85 pounds per acre per year for the entire region (table 17). If these acres were still being cropped without any conservation practices, the annual average change in soil organic carbon would be a loss of 107 pounds per acre per year. Thus, for these 11.2 million acres, the gain in soil organic carbon averages 192 pounds per acre compared to a cropped condition without conservation practices. Gains are generally similar in the eastern and western portions of the basin, as shown in figure 33. Gains in the eastern portion of the basin average 216 pounds per acre per year, compared to 181 pounds per acre per year in the western portion (table 17).

These gains are equivalent to a carbon dioxide emission reduction of 3.9 million U.S. tons of carbon dioxide for the region. However, the rate of emission reduction due to conservation practices varies considerably among acres in long-term conserving cover, as indicated by the wide range of average annual gains in soil organic carbon shown in figure 33.

Figure 33. Estimates of average annual gain in soil organic carbon due to conversion to long-term conserving cover in the Missouri River Basin



Note: About 11 percent of the acres in the eastern portion and 6 percent in the western portion of the basin have decreases in annual carbon gain compared to a cropped condition. Biomass production under long-term conserving cover is typically nitrogen limited. The higher biomass production and resulting crop residue from the fertilization of cropped acres can exceed the carbon benefits of long-term conserving cover under some conditions.

Effects of Practices on Nitrogen Loss

Baseline condition for cropped acres

Plant-available nitrogen sources include application of commercial fertilizer, application of manure, nitrogen produced by legume crops (soybeans, alfalfa, dry beans, and peas), a small amount of manure deposited by grazing livestock, and atmospheric nitrogen deposition. On average, these sources provide about 102 pounds of nitrogen per acre per year for cropped acres in the Missouri River Basin (table 18). Nitrogen sources are higher in the eastern portion of the basin, averaging 140 pounds per acre per year. Nitrogen sources in the western portion of the basin are about half as much as in the eastern portion, averaging 72 pounds per acre per year. Nitrogen from biofixation and from nitrogen applied as commercial fertilizer are lower in the western portion because of few acres of legume crops and the predominance of wheat and other small grain crops that require relatively smaller amounts of nitrogen.

Model simulations show that about 75 percent of these nitrogen sources are taken up by the crop and removed at harvest in the crop yield, on average, and the remainder is lost from the field through various loss pathways.[21]

For the baseline conservation condition, the annual average amount of nitrogen lost from the field, other than the nitrogen removed from the field at harvest, is about 23.4 pounds per acre—27.3 pounds per acre in the eastern portion of the basin and 20.4 pounds per acre in the western portion (table 18). These nitrogen loss pathways are (fig. 34 and table 18)—

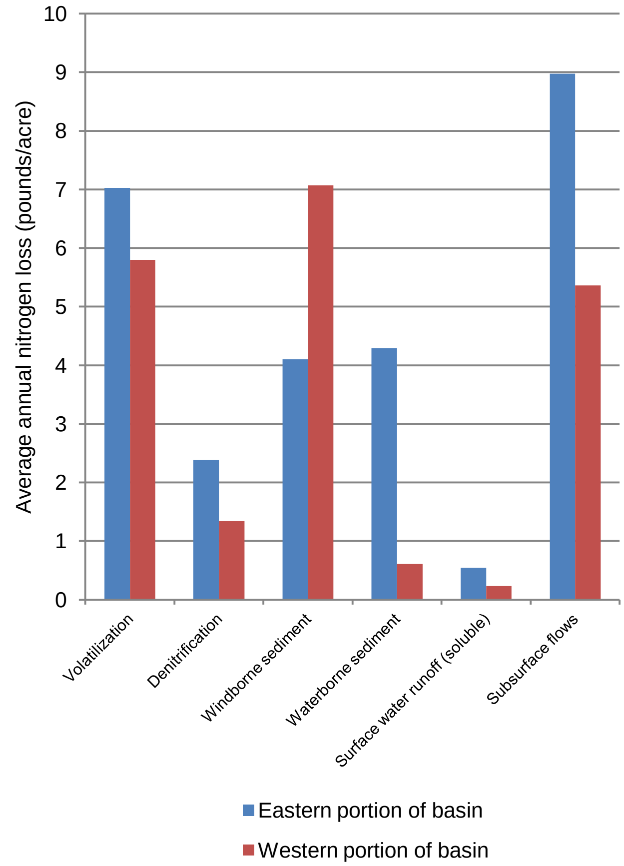
- nitrogen lost due to volatilization associated primarily with fertilizer and manure application and decomposition of residue (average of 6.3 pounds per acre per year);
- nitrogen returned to the atmosphere through denitrification (average of 1.8 pounds per acre per year);
- nitrogen lost with windborne sediment (average of 5.8 pounds per acre per year);
- nitrogen lost with surface runoff (average of 2.6 pounds per acre per year), most of which is nitrogen lost with waterborne sediment; and
- nitrogen loss in subsurface flow pathways (average of 6.9 pounds per acre per year).

Losses are higher in the eastern portion of the basin than in the western portion for all loss pathways except nitrogen lost with windborne sediment, which is significantly higher in the western portion.

In the eastern portion of the basin, nitrogen volatilization and nitrogen loss in subsurface flows are the dominant loss pathways for about two-thirds of the cropped acres. In the western portion, nitrogen lost with windborne sediment is the dominant loss pathway for 42 percent of cropped acres, followed by nitrogen volatilization for 35 percent of cropped acres. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.)

Nitrogen loss in subsurface flows is higher for irrigated acres than for non-irrigated acres, especially in the western portion of the basin (table 18). For the baseline conservation condition, nitrogen loss in subsurface flows for irrigated acres averages 14.0 pounds per acre in the eastern portion and 15.6 pounds per acre in the western portion, compared to 8.4 pounds per acre and 3.3 pounds per acre for non-irrigated acres, respectively.

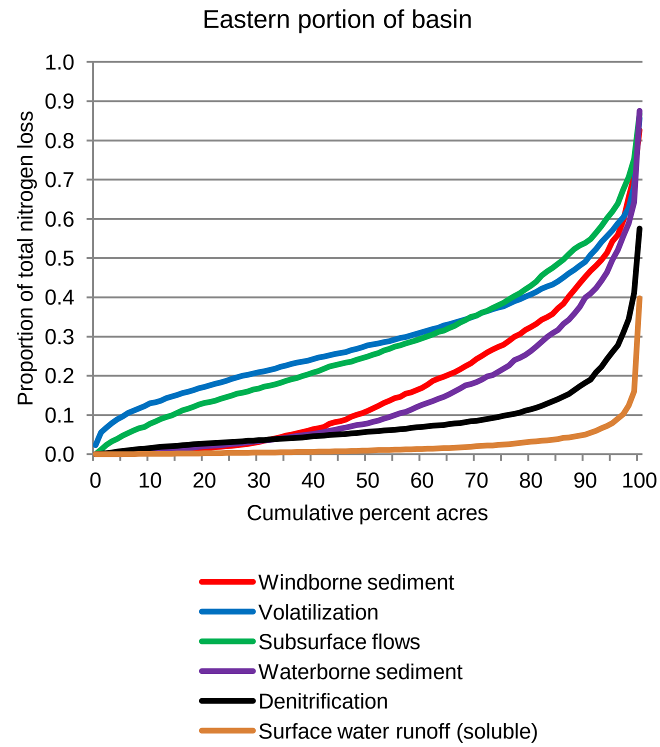
Figure 34. Average annual nitrogen loss by loss pathway, Missouri River Basin, baseline conservation condition



[21] A small amount may also build up in the soil or be mined from the soil, as shown in table 18 for the variable "change in soil nitrogen."

As shown in figure 35, the proportion of total nitrogen loss for all loss pathways varies considerably throughout the region. (In figure 35, the horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same sample point on another curve.)

Figure 35. Cumulative distributions of proportions of nitrogen lost through six loss pathways, Missouri River Basin



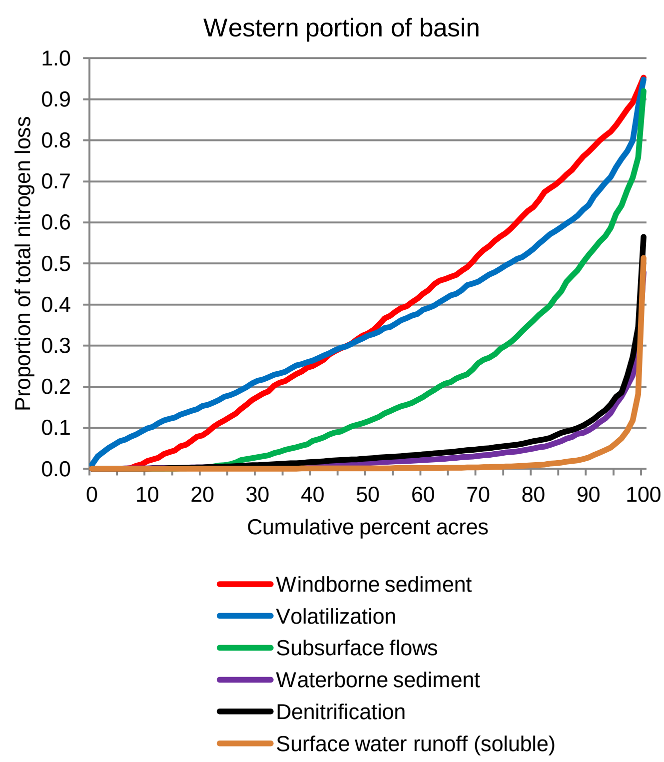


Table 18. Field-level effects of conservation practices on nitrogen sources and nitrogen loss pathways for cropped acres in the Missouri River Basin

Model simulated outcome	Average annual values in pounds per acre Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Entire region		
Nitrogen sources				
Atmospheric deposition	5	5	0	0
Bio-fixation by legumes	31	30	-2	-5
Nitrogen applied as commercial fertilizer and manure	65	91	26	28
All nitrogen sources	102	126	24	19
Nitrogen in crop yield removed at harvest	76	87	11*	12*
Nitrogen loss pathways				
Nitrogen loss by volatilization	6.3	7.1	0.8	11
Nitrogen loss through denitrification	1.8	1.9	0.1	4
Nitrogen lost with windborne sediment	5.8	10.7	5.0	46
Nitrogen loss with surface runoff, including waterborne sediment	2.6	6.2	3.6	58
Nitrogen loss with surface water (soluble)	0.4	1.3	0.9	71
Nitrogen loss with waterborne sediment	2.2	4.9	2.7	55
Nitrogen loss in subsurface flow pathways	6.9	12.5	5.6	45
Total nitrogen loss for all loss pathways	23.4	38.4	15.0	39
Change in soil nitrogen	0.8	-0.5	-1.3	--
		Eastern portion of basin		
Nitrogen sources				
Atmospheric deposition	7	7	0	0
Bio-fixation by legumes	60	58	-2	-4
Nitrogen applied as commercial fertilizer and manure	73	92	19	21
All nitrogen sources	140	157	17	11
Nitrogen in crop yield removed at harvest	105	115	10*	9*
Nitrogen loss pathways				
Nitrogen loss by volatilization	7.0	7.0	0.0	0
Nitrogen loss through denitrification	2.4	2.4	0.0	0
Nitrogen lost with windborne sediment	4.1	7.7	3.6	47
Nitrogen loss with surface runoff, including waterborne sediment	4.8	11.0	6.2	56
Nitrogen loss with surface water (soluble)	0.5	1.9	1.4	72
Nitrogen loss with waterborne sediment	4.3	9.1	4.8	53
Nitrogen loss in subsurface flow pathways	9.0	11.4	2.4	21
Irrigated acres	14.0	14.8	0.7	5
Non-irrigated acres	8.4	10.9	2.6	24
Total nitrogen loss for all loss pathways	27.3	39.5	12.2	31
Change in soil nitrogen	6.6	1.6	-5.0	--
		Western portion of basin		
Nitrogen sources				
Atmospheric deposition	4	4	0	0
Bio-fixation by legumes	9	8	-1	-13
Nitrogen applied as commercial fertilizer and manure	60	90	30	34
All nitrogen sources	72	101	29	29
Nitrogen in crop yield removed at harvest	54	65	11*	17*
Nitrogen loss pathways				
Nitrogen loss by volatilization	5.8	7.2	1.4	20
Nitrogen loss through denitrification	1.3	1.5	.02	11
Nitrogen lost with windborne sediment	7.1	13.0	6.0	46
Nitrogen loss with surface runoff, including waterborne sediment	0.8	2.5	1.6	66
Nitrogen loss with surface water (soluble)	0.2	0.8	0.5	69
Nitrogen loss with waterborne sediment	0.6	1.7	1.1	64
Nitrogen loss in subsurface flow pathways	5.4	13.4	8.0	60
Irrigated acres	15.6	28.7	13.1	46
Non-irrigated acres	3.3	10.3	7.0	68
Total nitrogen loss for all loss pathways	20.4	37.6	17.2	46
Change in soil nitrogen	-3.6	-2.1	1.5	--

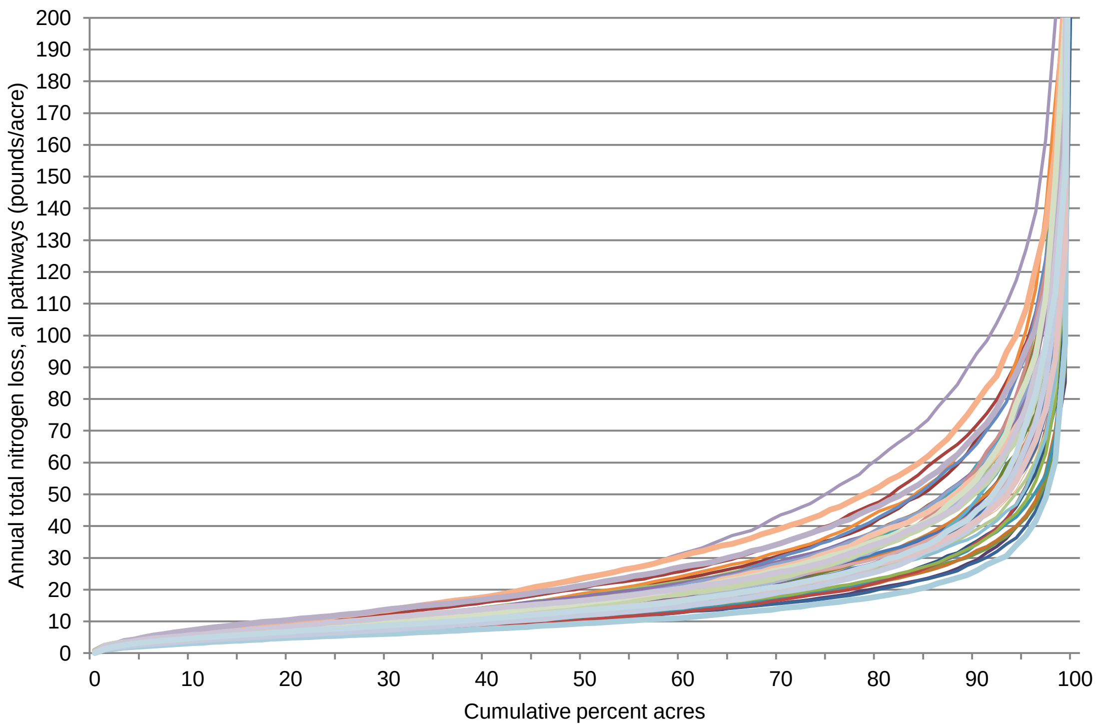
* The reduction in yield reflects the increase in nutrients in the representation in the no-practice scenario for nutrient management.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 29 subregions.

Model simulations for the baseline conservation condition indicate that some cropped acres in the Missouri River Basin are much more susceptible to the effects of weather than other acres and lose much larger amounts of nitrogen. Figure 36 shows that, with the conservation practices currently in use in the Missouri River Basin, annual nitrogen loss from fields can exceed 50 pounds per acre for about 25 percent of the acres in one or more years. In years with the most extreme weather, up to 8 percent of the acres lose over 100 pounds of nitrogen.

Figure 36 also shows that acres with high nitrogen losses through all loss pathways are restricted to a minority of the acres within the region. Nearly 60 percent of cropped acres have relatively low levels of nitrogen loss (less than 30 pounds per acre) under all conditions, including years with high precipitation. About 45 percent of cropped acres have less than 20 pounds per acre of nitrogen loss in all years.

Figure 36. Distribution of annual total nitrogen loss (all loss pathways, baseline conservation condition) for each year of the 47-year model simulation, Missouri River Basin



Note: This figure shows how annual total nitrogen loss (pounds per acre per year) varied within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total nitrogen loss varied over the region in that year, starting with the acres with the lowest total nitrogen loss and increasing to the acres with the highest total nitrogen loss. The family of curves shows how annual total nitrogen loss varied from year to year.

Note: Nitrogen loss is highest for the year 1993 in figure 36, which has the highest annual precipitation over the 47 years in both portions of the basin.

Effects of conservation practices on cropped acres

Total nitrogen loss, all pathways. Model simulations show that the conservation practices in use in the region have reduced total nitrogen loss from cropped acres by an average of 15 pounds per acre per year, representing a 39-percent reduction, on average (table 18). Without conservation practices, about 31 percent of the cropped acres would have average annual total nitrogen loss exceeding 40 pounds per acre per year; with conservation practices, 10 percent of acres exceed this level of loss (fig. 37).

The use of conservation practices is more effective in reducing total nitrogen losses from fields in the western portion of the basin than in the eastern portion. In the western portion, the conservation practices in use have reduced total nitrogen loss from cropped acres by an average of 17 pounds per acre per year, representing a 46-percent reduction compared to an average reduction of 12 pounds per acre per year in the eastern portion, representing a 31-percent reduction (table 18).

The effects of conservation practices vary from acre to acre, as shown in figure 38, depending on the extent to which conservation practices are used and the inherent vulnerability of the soils to losses through the various pathways. Most acres have reductions of 10 pounds of nitrogen or more due to conservation practices in both the eastern and the western portions of the basin.

Figure 38 also shows that about 6 percent of the acres in the region have an *increase* in total nitrogen loss due to conservation practice use—10 percent of cropped acres in the eastern portion of the basin and 3 percent in the western portion. Most of these increases are small; only 2 percent of the acres have increases of more than 3 pounds per acre. This result primarily occurs on soils with relatively high soil nitrogen content and generally with low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. Cropping systems that include legumes can have a higher soil nitrogen stock in the baseline conditions because legumes produce proportionately less biofixation of nitrogen under the higher fertilization rates simulated in the no-practice scenario.

Figure 37. Estimates of average annual total nitrogen loss for cropped acres in the Missouri River Basin

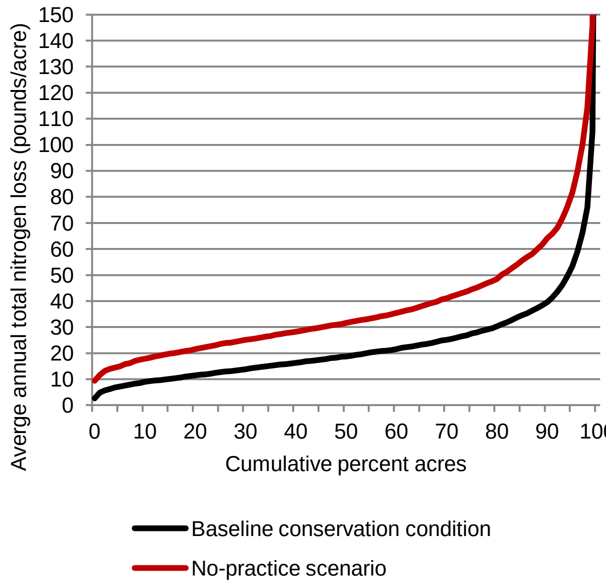
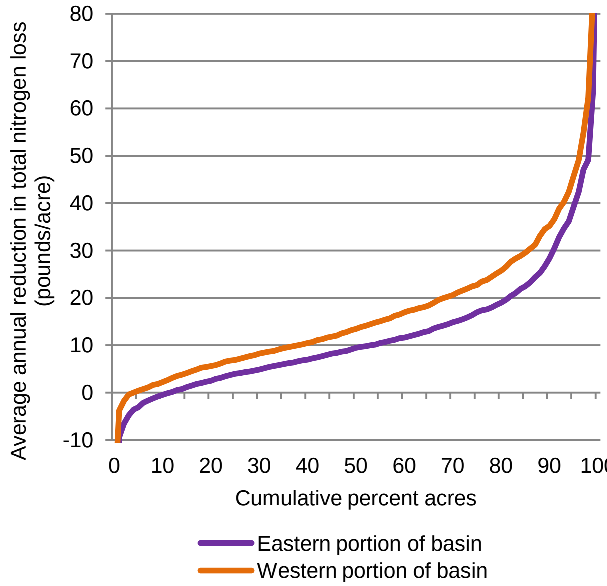


Figure 38. Estimates of average annual reduction in total nitrogen loss due to the use of conservation practices on cropped acres in the Missouri River Basin



Note: See text for discussion of conditions that result in lower total nitrogen loss in the no-practice scenario than in the baseline conservation condition for 6 percent of the acres in the region.

Nitrogen lost with windborne sediment. Nitrogen lost with windborne sediment is the loss pathway with the most nitrogen loss in the western portion of the basin—7.1 pounds per acre per year in the baseline conservation condition (table 18). Nitrogen loss with windborne sediment is also significant in the eastern portion, where the average loss to this pathway is 4.1 pounds per acre per year.

In the western portion of the basin, conservation practice use has reduced nitrogen lost with windborne sediment from cropped acres by an average of 6 pounds per acre per year, representing an average reduction of 46 percent (table 18, fig. 39). Without conservation practices, about 31 percent of the cropped acres would have nitrogen lost with windborne sediment in excess of an average of 15 pounds per acre per year, compared to only 11 percent in the baseline (fig. 39).

In the eastern portion, conservation practice use has reduced nitrogen lost with windborne sediment by 3.6 pounds per acre per year, representing a 47-percent reduction.

Figure 40 shows the distributions of the reductions in nitrogen lost with windborne sediment. The largest reductions are in the western portion of the basin, where wind erosion losses are highest; reductions are larger than 10 pounds per acre for about 20 percent of the acres. For a few acres, reductions exceed 20 pounds per acre per year. Figure 40 also shows, however, that about half of the cropped acres in the western portion of the basin and 70 percent of cropped acres in the eastern portion have average reductions of less than 5 pounds per acre due to conservation practices.[22]

[22] Small negative reductions in windborne sediment, shown in figure 27, also result in small negative reductions in nitrogen lost with windborne sediment, shown in figure 40.

Figure 39. Estimates of average annual nitrogen lost with windborne sediment for cropped acres in the Missouri River Basin

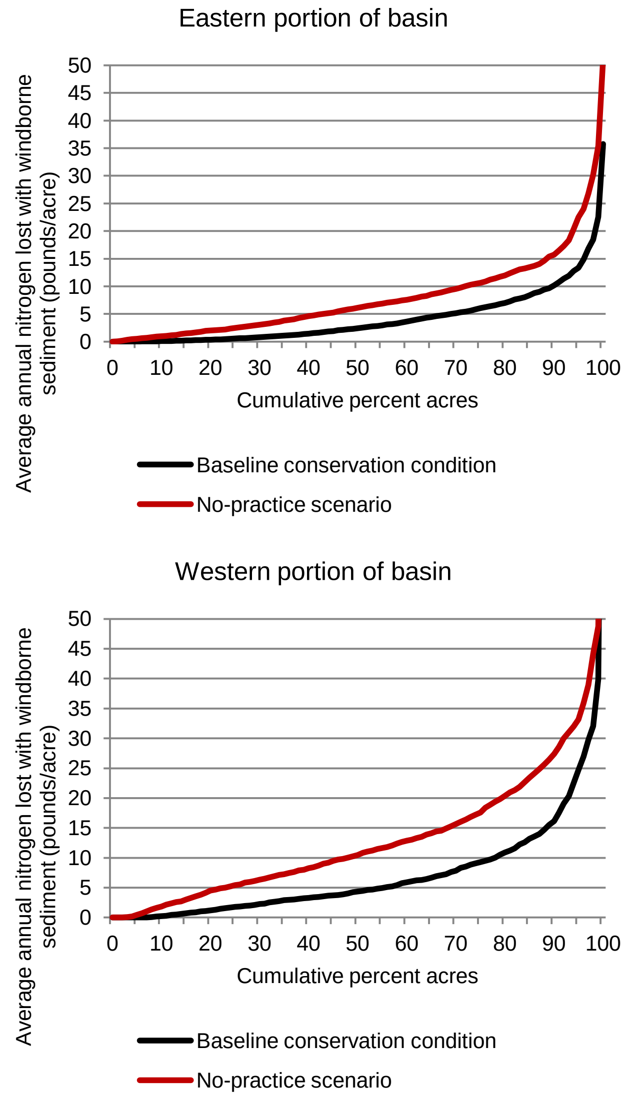
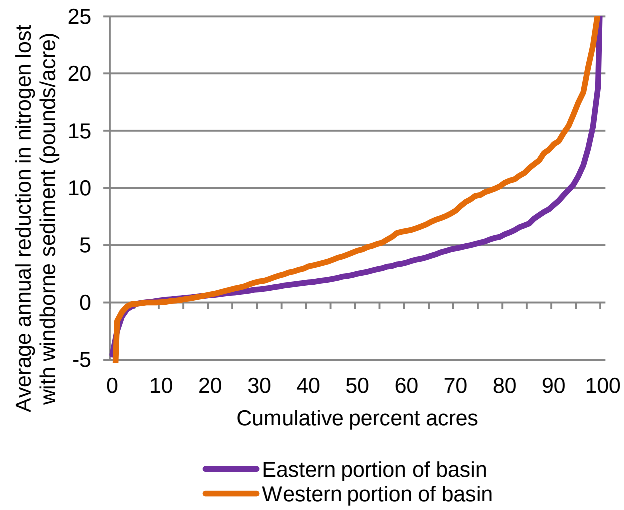


Figure 40. Estimates of average annual reductions in nitrogen lost with windborne sediment due to the use of conservation practices on cropped acres in the Missouri River Basin



Nitrogen loss in subsurface flows. Conservation practices are effective in reducing nitrogen loss in subsurface flows on some acres in the western portion of the basin, but make little difference on most acres in the eastern portion and even result in increases in nitrogen loss in subsurface flows for 22 percent of cropped acres for the entire region (figs. 41 and 42). (Increases in nitrogen loss in subsurface flows due to conservation practices are represented in figure 42 as negative reductions.) On average for the entire region, conservation practices have reduced nitrogen loss in subsurface flows from 12.5 pounds per acre without practices to 6.9 pounds per acre with practices, representing an average reduction of 5.6 pounds per acre per year (45-percent reduction) (table 18). Average reduction is much higher in the western portion, averaging 8.0 pounds per acre (60-percent reduction), compared to an average of only 2.4 pounds per acre in the eastern portion (21-percent reduction).

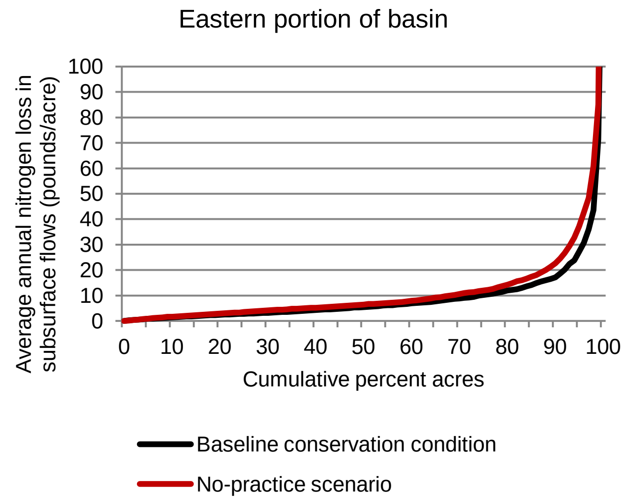
Some of the differences between reductions in nitrogen loss in subsurface flows between the eastern and western portions of the basin are due to more effective conservation practice use in the western portion of the basin on irrigated acres. In the western portion of the basin, nitrogen loss in subsurface flows has been reduced by an average of 13.1 pounds per acre for irrigated acres, representing a 46-percent reduction (table 18). In the eastern portion of the basin, the average reduction is only 0.7 pounds per acre on irrigated acres, representing a 5-percent reduction.

For some acres, conservation practice use has been effective in reducing nitrogen loss in subsurface flows. Figure 42 shows that reductions in average annual nitrogen loss in subsurface flows exceed 10 pounds per acre for 26 percent of cropped acres in the western portion of the basin and 8 percent in the eastern portion.

The majority of cropped acres in the eastern portion, however, have reductions less than 1 pound per acre, including 40 percent with negative reductions. Most of the negative reductions are small; only 15 percent of cropped acres in the eastern portion of the basin have increases of nitrogen loss in subsurface flows greater than 2 pounds per acre due to conservation practices. In the western portion, 3 percent of cropped acres have negative reductions greater than 2 pounds per acre per year.

The increases in nitrogen loss in subsurface flows due to conservation practices are largely due to relatively weak nutrient management practices on acres with erosion control treatment. A portion of the reduction in nitrogen lost with surface runoff is re-routed to subsurface loss pathways, resulting in gains or only small reductions in nitrogen loss in subsurface flows. This re-routing of surface water runoff to subsurface flow pathways results in additional nitrogen being leached from the soil, diminishing and sometimes offsetting the overall positive effects of conservation practices on total nitrogen loss. These model simulation results underscore the importance of pairing water erosion control practices with effective nutrient management practices so that the full suite of conservation practices will provide the environmental protection needed.

Figure 41. Estimates of average annual nitrogen loss in subsurface flows for cropped acres in the Missouri River Basin



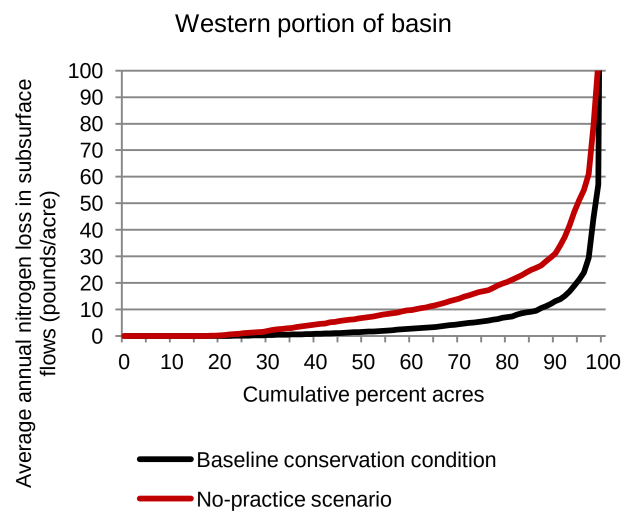
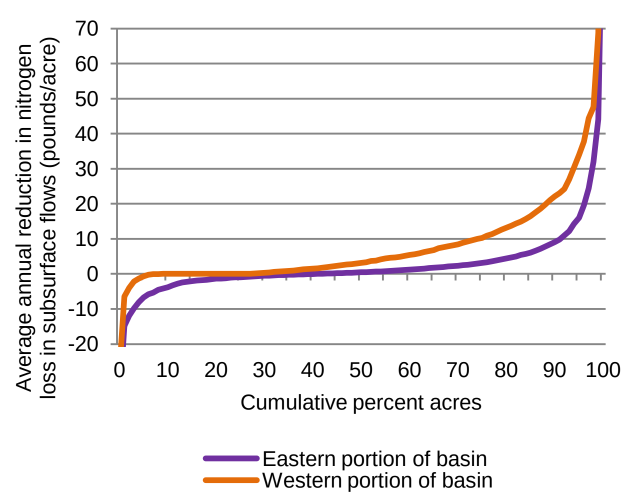


Figure 42. Estimates of average annual reductions in nitrogen loss in subsurface flows due to the use of conservation practices on cropped acres in the Missouri River Basin



Nitrogen lost with surface runoff. Although nitrogen lost with surface runoff, including waterborne sediment, is low relative to losses in other pathways for most acres in this region, conservation practices have been effective in reducing these losses. Model simulations show that, on average, nitrogen lost with surface runoff has been reduced 58 percent due to use of conservation practices in the region (table 18). In the eastern portion of the basin, conservation practices have reduced nitrogen lost with surface runoff from an average of 11.0 pounds per acre without practices to 4.8 pounds per acre with practices, representing an average reduction of 6.2 pounds per acre per year (56-percent reduction) (table 18). Average reduction is lower in the western portion, averaging 1.6 pounds per acre, but results in a higher percent reduction (66-percent reduction).

Figure 43 shows that about 47 percent of the cropped acres have reductions in nitrogen lost with surface runoff greater than 5 pounds per acre per year due to conservation practice use in the eastern portion of the basin, compared to only 7 percent in the western portion.

Nitrogen volatilization loss. As shown in figure 35, nitrogen loss through volatilization is an important loss pathway in both the eastern and western portions of the basin. For many acres in this region, nitrogen volatilization is the dominant nitrogen loss pathway. However, conservation practices in use within the region are not as effective at reducing these losses as they are for other nitrogen loss pathways (fig. 44). Reduced tillage practices which leaves more crop residue on the soil surface and less nitrogen fertilizer and manure incorporated can contribute to increased nitrogen volatilization. Overall for the region, conservation practices have reduced nitrogen volatilization losses by an average of 0.8 pound per acre, reducing loss from an average of 7.1 pounds per acre without conservation practices to an average of 6.3 pounds per acre for the baseline (table 18).

Reductions in nitrogen volatilization are slightly higher in the western portion of the basin than in the eastern portion, due in part to higher soil pH and warmer, drier climates in the west. In both portions of the basin, however, conservation practice use has enhanced nitrogen volatilization on some acres, as shown by the negative reductions in figure 44. In the eastern portion of the basin, 47 percent of cropped acres have increases in nitrogen volatilization with conservation practices use. Most of these increases are small; 20 percent of cropped acres have increases greater than 2 pounds per acre per year. In the western portion, conservation practices have increased nitrogen volatilization losses on 24 percent of cropped acres, with losses greater than 2 pounds per acre per year for 8 percent of cropped acres.

Figure 43. Estimates of average annual reductions in nitrogen loss with surface runoff, including waterborne sediment, due to the use of conservation practices on cropped acres in the Missouri River Basin

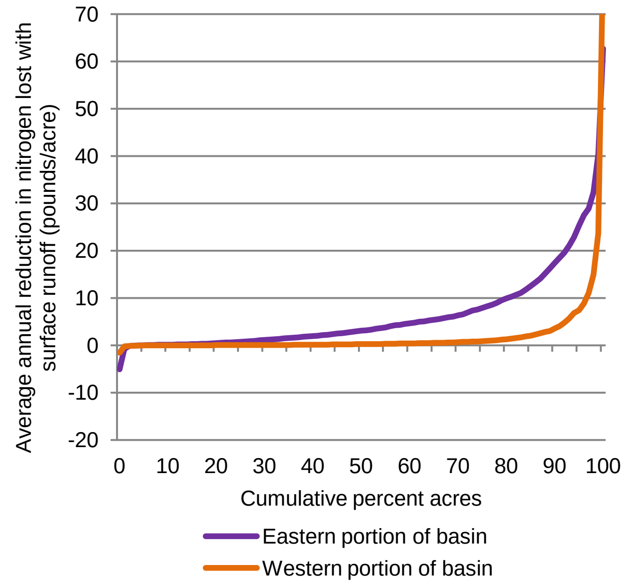
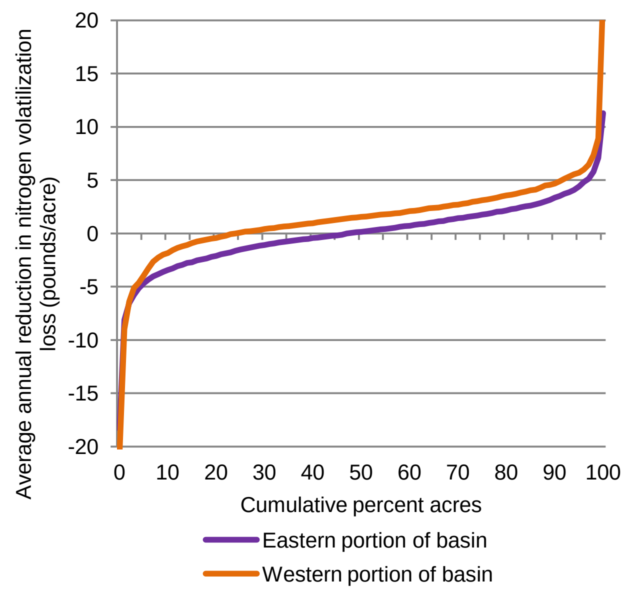


Figure 44. Estimates of average annual reductions in nitrogen volatilization due to the use of conservation practices on cropped acres in the Missouri River Basin



Tradeoffs in Conservation Treatment

Conservation practices applied on cropland are, for the most part, synergistic. The benefits accumulate as more practices are added to the designed systems. However, when only a single resource concern is addressed (such as soil erosion), antagonism between the practices and other resource concerns may occur. That is why it is essential that all resource concerns be considered during the conservation planning process. Most of the time the tradeoffs are much smaller than the magnitude of the primary resource concerns. Common examples are:

- Terraces and conservation tillage are planned to solve a serious water erosion problem. However, in some areas there may be concern about seeps at the lower part of the field. The planned practices will solve the erosion problem, but could exacerbate the seep problem under some conditions. Ignoring that fact does not make for an adequate conservation plan.
- Conservation tillage is planned for erosion control on a cropland field with a high water table. The reduction in runoff may increase leaching of nitrates into the shallow water table. A complete and comprehensive conservation plan would provide a suite of conservation practices that addressed both problems.
- A nutrient management plan reduces the amount of manure added to a field to reduce the loss of nutrients to surface or groundwater. However, the reduction in organic material added to the field may reduce the soil organic matter content or reduce the rate of change in soil organic matter.
- About 6 percent of cropped acres in this region have an increase in total nitrogen loss (fig. 38) and 22 percent of cropped acres have an increase in nitrogen loss in subsurface flows due to conservation practice use (fig. 42). This result occurs primarily on soils with relatively high soil nitrogen content and generally low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. For these fields, the nutrient management component of a farmer's conservation plan would need to be enhanced to reduce or eliminate the negative effects of soil erosion control practices on nitrogen loss.

A *comprehensive planning process* is used to identify the appropriate combination of practices needed to address multiple resource concerns by taking into account the specific inherent vulnerabilities associated with each field. To ensure that proper consideration is given to the effects of conservation practices on *all* of the resource concerns, USDA/NRCS developed a comprehensive planning tool referred to as CPPE (Conservation Practice Physical Effects). The CPPE is included in the Field Office Technical Guide. Conservation planners are expected to use CPPE as a reference to ensure that *all* resource concerns are addressed in conservation plans.

Land in long-term conserving cover

Conversion of cropped acres to conserving cover, such as grasses and, in some cases, trees, reduces the nitrogen sources to about 10 pounds per acre for land in long-term conserving cover in this region (table 19). Of this, 30 percent comes from atmospheric deposition (wet and dry) and 70 percent comes from legumes, such as forbs and clovers. Nitrogen sources are higher in the eastern portion of the basin, averaging 16 pounds per acre per year, compared to 7 pounds per acre per year in the western portion. Since there is no harvest and removal associated with these acres, the nitrogen taken up by the plants is recycled each year when the plants die and decompose. In addition, nitrogen stored in the soil can be brought to the surface by plant uptake and decomposition. These surface deposits of nitrogen are subject to the forces of wind and water and some nitrogen is lost from the fields each year.

Nitrogen loss from land in long-term conserving cover averages only about 8.4 pounds per acre per year—10.3 pounds per acre in the eastern portion of the basin and 7.5 pounds per acre per year in the western portion, on average.

Converting cropped acres to long-term conserving cover is very effective in reducing total nitrogen loss, as demonstrated in figures 45–47 and table 19. The figures also show, however, that reductions are much higher for some acres than others.

Total nitrogen loss has been reduced by an average of 36 pounds per acre per year—about 81 percent—on the 11.2 million acres in long-term conserving cover in this region, compared to conditions that would be expected had the acres remained in crops without use of conservation practices.

Nitrogen loss for loss pathways other than nitrogen volatilization and denitrification have been reduced by more than 90 percent, on average (table 19). Reductions of nitrogen loss through denitrification averages 73 percent for the region; denitrification losses in the region average only about 0.4 pounds per acre for land in long-term conserving cover in this region.

Converting cropped acres to long-term conserving cover had little net effect on nitrogen volatilization losses (table 19). About half of the acres had increases in nitrogen volatilization losses when converted to long-term conserving cover, and about half had reductions in nitrogen volatilization losses. Nitrogen volatilization represents, on average, about 85 percent of total nitrogen loss for land in long-term conserving cover in this region.

Nitrogen volatilization from long-term conserving cover can occur in two ways: (1) living plant material can influence ammonia loss to the atmosphere, and (2) decomposing plant material, especially from nitrogen-rich legumes and other forbs, release ammonia directly to the atmosphere. The presence of high levels of urease on the soil surface promotes ammonia volatilization activity. Plants can both emit and absorb ammonia to the atmosphere because this compound can be used directly as a precursor for organic nitrogen products. Actively growing plants also influence the soil's temperature and water regimes, which in turn can regulate the rate of ammonia volatilization from the soil surface.

Figure 45. Estimates of average annual total nitrogen loss for land in long-term conserving cover in the Missouri River Basin

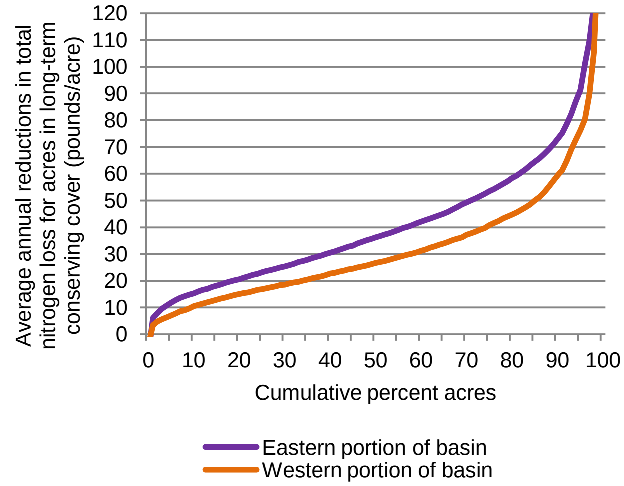


Figure 46. Estimates of average annual nitrogen lost with windborne sediment for land in long-term conserving cover in the Missouri River Basin

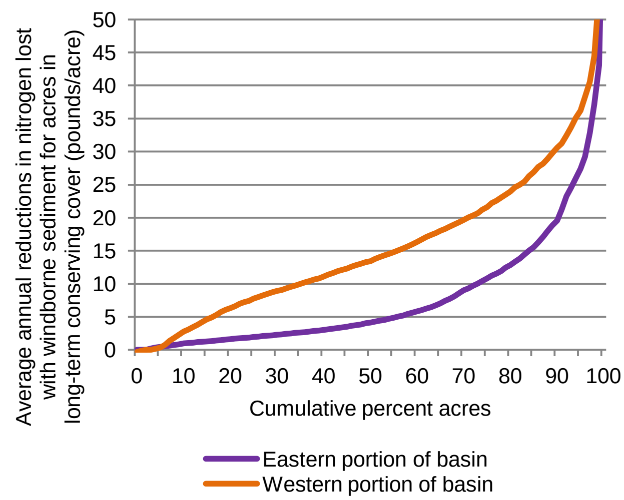


Figure 47. Estimates of average annual nitrogen loss in subsurface flows for land in long-term conserving cover in the Missouri River Basin

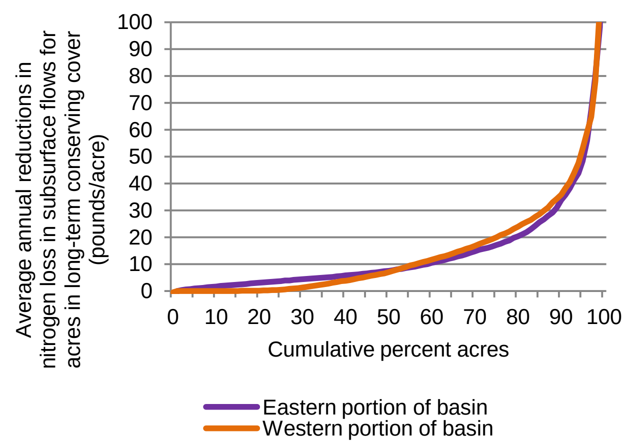


Table 19. Effects of conservation practices on nitrogen sources and nitrogen loss pathways for land in long-term conserving cover (11.2 million acres), Missouri River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Average annual values in pounds per acre			
	Entire region			
Nitrogen sources				
Atmospheric deposition	3	3	0	0
Bio-fixation by legumes	7	20	14	68
Nitrogen applied as commercial fertilizer and manure	0	82	82	100
All nitrogen sources	10	106	96	91
Nitrogen in crop yield removed at harvest	0.1*	67	67	100
Nitrogen loss pathways				
Nitrogen loss by volatilization	7.1	7.2	<0.1	1
Nitrogen loss through denitrification	0.4	1.5	1.1	73
Nitrogen lost with windborne sediment	<0.1	13.4	13.4	100
Nitrogen loss with surface runoff, including waterborne sediment	0.3	7.1	6.9	96
Nitrogen loss with surface water (soluble)	<0.1	1.2	1.2	98
Nitrogen loss with waterborne sediment	0.3	5.9	5.7	95
Nitrogen loss in subsurface flow pathways	0.5	15.1	14.6	97
Total nitrogen loss for all pathways	8.4	44.3	36.0	81
Change in soil nitrogen	0.7	-6.6	-7.2	--
	Eastern portion of basin			
Nitrogen sources				
Atmospheric deposition	5	5	0	0
Bio-fixation by legumes	10	57	47	82
Nitrogen applied as commercial fertilizer and manure	0	89	89	100
All nitrogen sources	16	151	136	90
Nitrogen in crop yield removed at harvest	0.3*	107	107	100
Nitrogen loss pathways				
Nitrogen loss by volatilization	7.5	7.3	-0.2	-3
Nitrogen loss through denitrification	0.7	2.7	2.0	74
Nitrogen lost with windborne sediment	<0.1	8.0	8.0	100
Nitrogen loss with surface runoff, including waterborne sediment	0.7	18.7	18.0	96
Nitrogen loss with surface water (soluble)	<0.1	2.4	2.3	98
Nitrogen loss with waterborne sediment	0.7	16.4	15.7	96
Nitrogen loss in subsurface flow pathways	1.3	15.7	14.4	91
Total nitrogen loss for all pathways	10.3	52.4	42.1	80
Change in soil nitrogen	4.4	-8.3	-12.7	--
	Western portion of basin			
Nitrogen sources				
Atmospheric deposition	2	2	0	0
Bio-fixation by legumes	5	4	-1	-28
Nitrogen applied as commercial fertilizer and manure	0	79	79	100
All nitrogen sources	7	85	78	92
Nitrogen in crop yield removed at harvest	<0.1	50	50	100
Nitrogen loss pathways				
Nitrogen loss by volatilization	7.0	7.1	0.1	2
Nitrogen loss through denitrification	0.3	1.0	0.7	72
Nitrogen lost with windborne sediment	<0.1	15.8	15.8	100
Nitrogen loss with surface runoff, including waterborne sediment	0.1	2.0	1.9	95
Nitrogen loss with surface water (soluble)	<0.1	0.7	0.7	100
Nitrogen loss with waterborne sediment	<0.1	1.3	1.2	93
Nitrogen loss in subsurface flow pathways	0.1	14.8	14.7	99
Total nitrogen loss for all pathways	7.5	40.8	33.2	82
Change in soil nitrogen	-1.0	-5.8	-4.7	--

* Harvest was simulated on acres planted to trees where expected tree age is less than the 47 years included in the model simulation. At tree harvest time, the grass also is removed and replanted.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Effects of Practices on Phosphorus Loss

Phosphorus, like nitrogen, is an essential element needed for crop growth. Unlike nitrogen, phosphorus rarely occurs in a gaseous form so the agricultural model has no atmospheric component. Phosphorus compounds that are soluble in water are available for plants to use. Although total phosphorus is plentiful in the soil, only a small fraction is available at any one time for plant uptake. Farmers apply commercial phosphate fertilizers to supplement low quantities of plant-available phosphorus in the soil.

Throughout this report, phosphorus results are reported in terms of elemental phosphorus (i.e., not as the phosphate fertilizer equivalent).

Baseline condition for cropped acres

In the model simulations for the Missouri River Basin, about 14 pounds per acre of phosphorus are applied as commercial fertilizer or in manure to cropped acres, on average, in each year of the model simulation (table 20). Phosphorus applications are higher in the eastern portion of the basin, averaging 19 pounds per acre per year. Phosphorus applications in the western portion of the basin are about half as much as in the eastern portion, averaging 10 pounds per acre per year, because of the predominance of wheat and other close-grown crops.

Model simulations show that the amount of phosphorus taken up by the crop and removed at harvest in the crop yield is about 84 percent of the amount of phosphorus applied, on average. The remainder is lost from the field through various loss pathways. [23]

Total phosphorus loss for all loss pathways averages 1.71 pounds per acre per year in the baseline conservation condition—2.0 pounds per acre in the eastern portion of the basin and 1.5 pounds per acre in the western portion (table 20). These phosphorus loss pathways are—

- phosphorus lost with windborne sediment (average of 1.03 pounds per acre per year);
- phosphorus lost with waterborne sediment (average of 0.42 pound per acre per year);
- soluble phosphorus lost to surface water, including soluble phosphorus in surface water runoff, and soluble phosphorus that infiltrates into the soil profile but quickly returns to surface water either through quick return lateral flow or intercepted by drainage systems (average of 0.25 pounds per acre per year); and
- soluble phosphorus that percolates through the soil profile into the groundwater (average of 0.01 pound per acre per year).

Losses are higher in the eastern portion of the basin than in the western portion for all loss pathways except phosphorus lost with windborne sediment, which is significantly higher in the western portion.

[23] A small amount may also build up in the soil or be mined from the soil, as shown in table 19 for the variable "change in soil phosphorus."

In the eastern portion of the basin, phosphorus lost with windborne sediment is the dominant loss pathway for 48 percent of cropped acres and phosphorus lost with waterborne sediment is the dominant loss pathway for 33 percent of cropped acres. Soluble phosphorus lost to surface water is the dominant loss pathway for the remaining cropped acres. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.)

The bulk of phosphorus lost in the western portion of the basin is lost with windborne sediment. Windborne sediment is the dominant loss pathway in this portion of the basin for 82 percent of cropped acres. The dominant loss pathway for 12 percent of the cropped acres is soluble phosphorus lost to surface water and the dominant loss pathway for remaining acres is phosphorus lost with waterborne sediment for the remaining acres. A very small amount of soluble phosphorus is lost through percolation into groundwater.

As shown in figure 48, the proportion of total phosphorus loss for all loss pathways varies considerably throughout the region. (In figure 48, the horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same sample point on another curve.)

Figure 48. Cumulative distributions of the proportion of phosphorus lost through various loss pathways, Missouri River Basin, baseline conservation condition

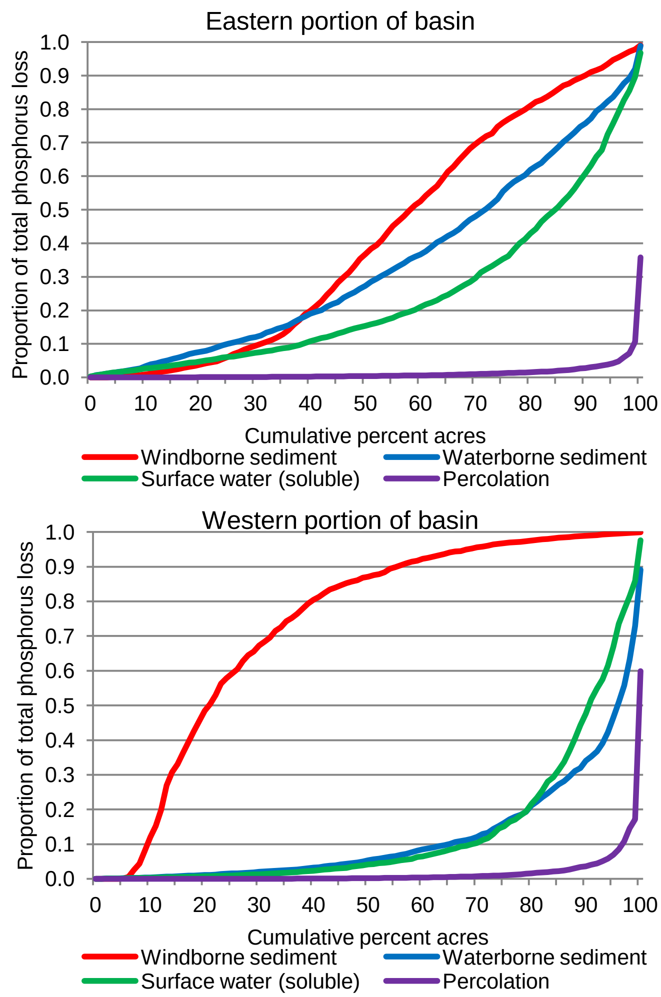


Table 20. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for cropped acres in the Missouri River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Average annual values in pounds per acre			
		Entire region		
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	14.2	20.0	5.8	29
Phosphorus in crop yield removed at harvest	11.9	13.3	1.4	11
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.03	2.46	1.42	58
Phosphorus lost to surface water (sediment attached and soluble)*	0.67	1.65	0.98	59
Soluble phosphorus lost to surface water*	0.25	0.43	0.18	42
Phosphorus loss with waterborne sediment	0.42	1.22	0.80	66
Soluble phosphorus loss to groundwater	0.01	0.01	<0.01	21
Total phosphorus loss for all loss pathways	1.71	4.12	2.41	58
Change in soil phosphorus	0.46	2.45	1.99	--
		Eastern portion of basin		
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	19.2	26.7	7.5	28
Phosphorus in crop yield removed at harvest	16.6	18.1	1.6	9
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.73	1.96	1.23	63
Phosphorus lost to surface water (sediment attached and soluble)*	1.25	3.01	1.76	58
Soluble phosphorus lost to surface water*	0.44	0.72	0.28	39
Phosphorus loss with waterborne sediment	0.82	2.30	1.48	64
Soluble phosphorus loss to groundwater	0.01	0.02	<0.01	25
Total phosphorus loss for all loss pathways	2.00	4.99	2.99	60
Change in soil phosphorus	0.45	3.41	2.96	--
		Western portion of basin		
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	10.3	14.8	4.5	30
Phosphorus in crop yield removed at harvest	8.3	9.6	1.3	14
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.27	2.84	1.57	55
Phosphorus lost to surface water (sediment attached and soluble)*	0.22	0.60	0.38	63
Soluble phosphorus lost to surface water*	0.10	0.20	0.10	49
Phosphorus loss with waterborne sediment	0.12	0.40	0.28	71
Soluble phosphorus loss to groundwater	0.01	0.01	<0.01	15
Total phosphorus loss for all loss pathways	1.50	3.45	1.95	57
Change in soil phosphorus	0.46	1.71	1.24	--

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

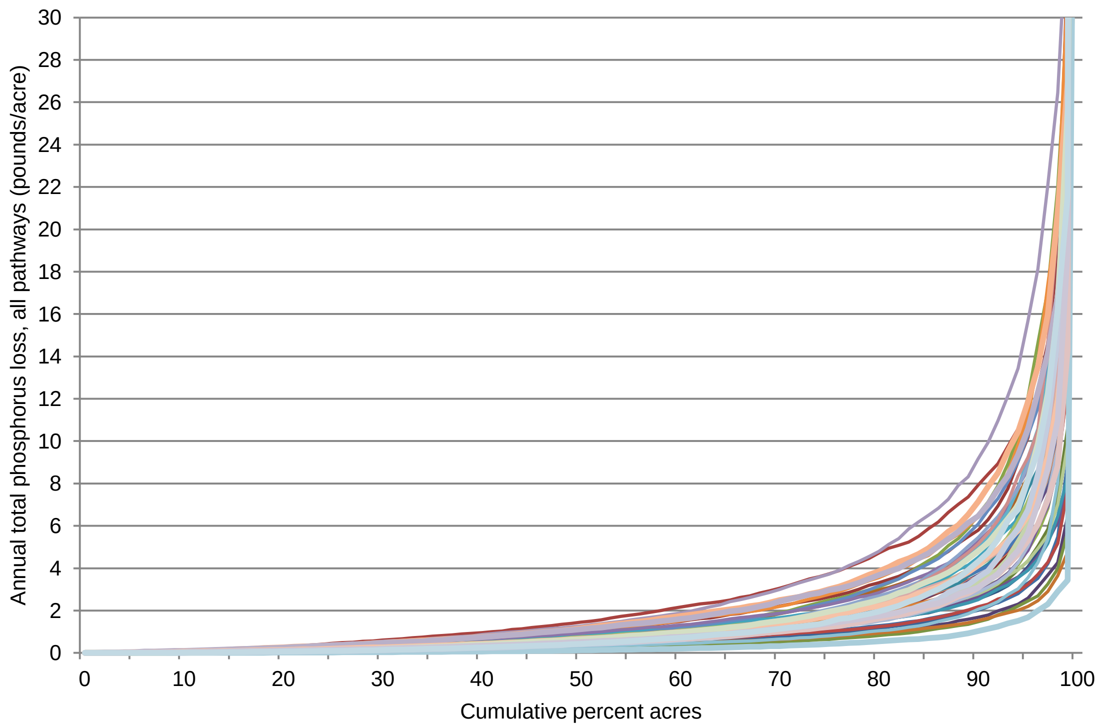
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 29 subregions.

Model simulations for the baseline conservation condition indicate that some cropped acres in the Missouri River Basin lose much larger amounts of phosphorus than other acres. Figure 49 shows that, with the conservation practices currently in use in the Missouri River Basin, annual phosphorus loss from fields can exceed 9 pounds per acre for about 10 percent of the acres in one or more years. In years with the most extreme weather, some acres lose over 20 pounds of phosphorus.

Figure 49 also shows that acres with high phosphorus losses through all loss pathways are restricted to a minority of the acres within the region. Nearly 60 percent of cropped acres have relatively low levels of nitrogen loss (less than 2 pounds per acre) under all conditions, including years with high precipitation. About 40 percent of cropped acres have less than 1 pound per acre of phosphorus loss in all years.

Figure 49. Distribution of annual total phosphorus loss (all loss pathways) for each year of the 47-year model simulation, Missouri River Basin



Note: This figure shows how annual total phosphorus loss (pounds per acre per year) varied within the region and from year to year in the model simulation on cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total phosphorus loss varied over the region in that year, starting with the acres with the lowest total phosphorus loss and increasing to the acres with the highest total phosphorus loss. The family of curves shows how annual total phosphorus loss varied from year to year.

Note: Phosphorus loss is highest for two years in figure 49—1993 and 1973. These two years are among the years with the highest annual precipitation over the 47 years in both portions of the basin.

Effects of conservation practices on cropped acres

Total phosphorus loss, all pathways. Model simulations show that the conservation practices in use in the region have reduced total phosphorus loss from cropped acres by an average of 2.4 pounds per acre per year, representing a 58 percent reduction, on average (table 20). Without conservation practices, about 37 percent of the cropped acres would have average annual total phosphorus loss exceeding 4 pounds per acre per year; with conservation practices, only 8 percent of acres exceed this level of loss (fig. 50).

The use of conservation practices is more effective in reducing total phosphorus losses from fields in the eastern portion of the basin than in the western portion (fig. 51). In the eastern portion, the conservation practices in use have reduced total phosphorus loss from cropped acres by an average of 3.0 pounds per acre per year, representing a 60-percent reduction compared to an average reduction of 2.0 pounds per acre per year in the western portion, representing a 57-percent reduction (table 20).

The effects of conservation practices vary from acre to acre, as shown in figure 51, depending on the extent to which conservation practices are used and the inherent vulnerability of the soils to losses through the various loss pathways. Most acres have reductions of 1 pound of phosphorus or more due to conservation practices in both the eastern and western portions of the basin.

Figure 50. Estimates of average annual total phosphorus loss (all loss pathways) for cropped acres in the Missouri River Basin

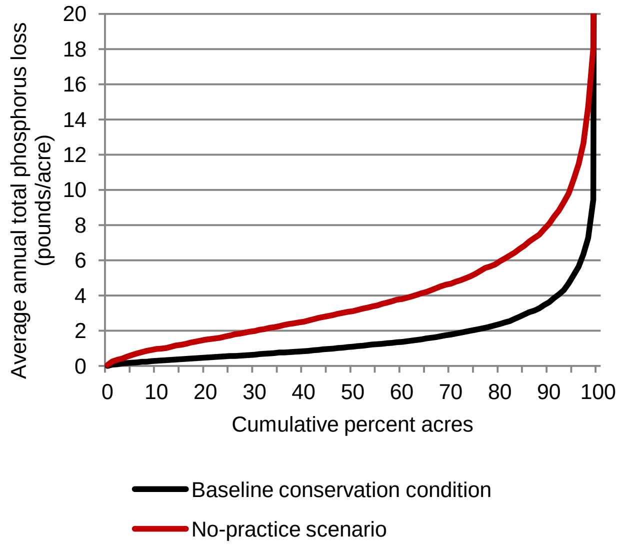
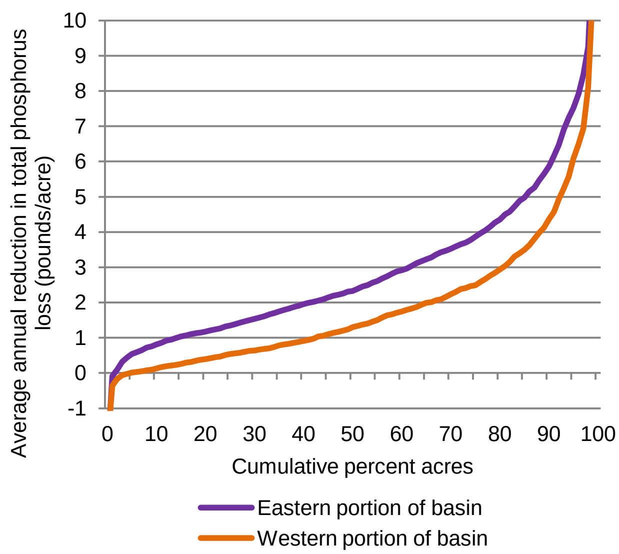


Figure 51. Estimates of average annual reduction in total phosphorus loss due to conservation practices on cropped acres in the Missouri River Basin



Note: The 2 percent of cropped acres with negative reductions in phosphorus loss due to conservation practices were on nearly level soils and soluble phosphorus was the primary loss pathway. In these cases, the additional tillage in the no-practice scenario reduced the loss of soluble phosphorus.

Phosphorus lost with windborne sediment. The majority (60 percent) of phosphorus lost from fields in the Missouri River basin is lost with windborne sediment. Of the 1.50 pounds per acre per year of total phosphorus loss in the western portion of the basin, 1.27 pounds per acre per year are lost with windborne sediment—85 percent. The proportion is less for the eastern portion—36 percent—but phosphorus lost with windborne sediment is the dominant loss pathway for 48 percent of cropped acres.

In the western portion of the basin, conservation practice use has reduced phosphorus lost with windborne sediment from cropped acres by an average of 1.57 pounds per acre per year, representing an average reduction of 55 percent (table 20, fig. 52). Without conservation practices, about 21 percent of the cropped acres would have phosphorus lost with windborne sediment in excess of an average of 4 pounds per acre per year, compared to only 6 percent in the baseline (fig. 52).

Conservation practices are also effective in reducing phosphorus lost with windborne sediment in the eastern portion of the basin (fig. 52). In the eastern portion, conservation practice use has reduced phosphorus lost with windborne sediment by 1.23 pounds per acre per year, representing a 63-percent reduction (table 20).

Figure 53 shows the distributions of the reductions in phosphorus lost with windborne sediment. The largest reductions are in the western portion of the basin, where wind erosion losses are highest. About half of the acres in both regions have reductions of 1 pound per acre or more due to conservation practices.[24]

[24] Small negative reductions in windborne sediment, shown in figure 27, also result in small negative reductions in phosphorus lost with windborne sediment for about 1 percent of cropped acres in the region, shown in figure 53.

Figure 52. Estimates of average annual phosphorus lost with windborne sediment for cropped acres in the Missouri River Basin

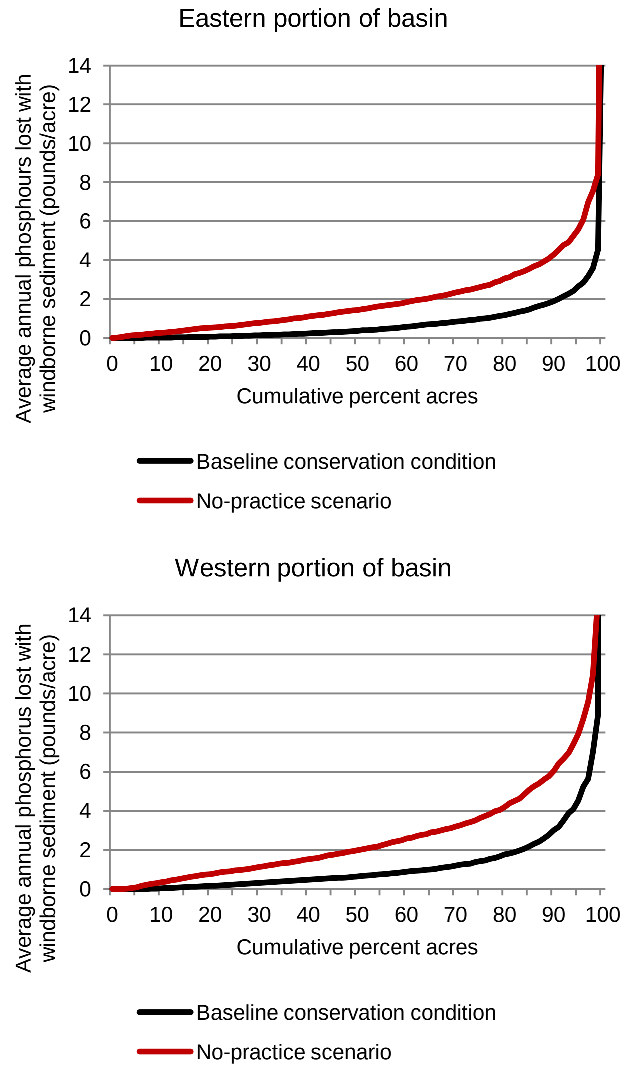
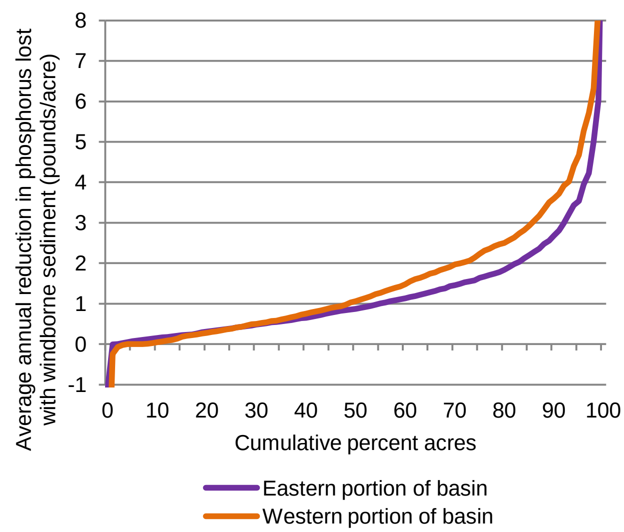


Figure 53. Estimates of average annual reduction in phosphorus lost with windborne sediment due to conservation practices for cropped acres in the Missouri River Basin

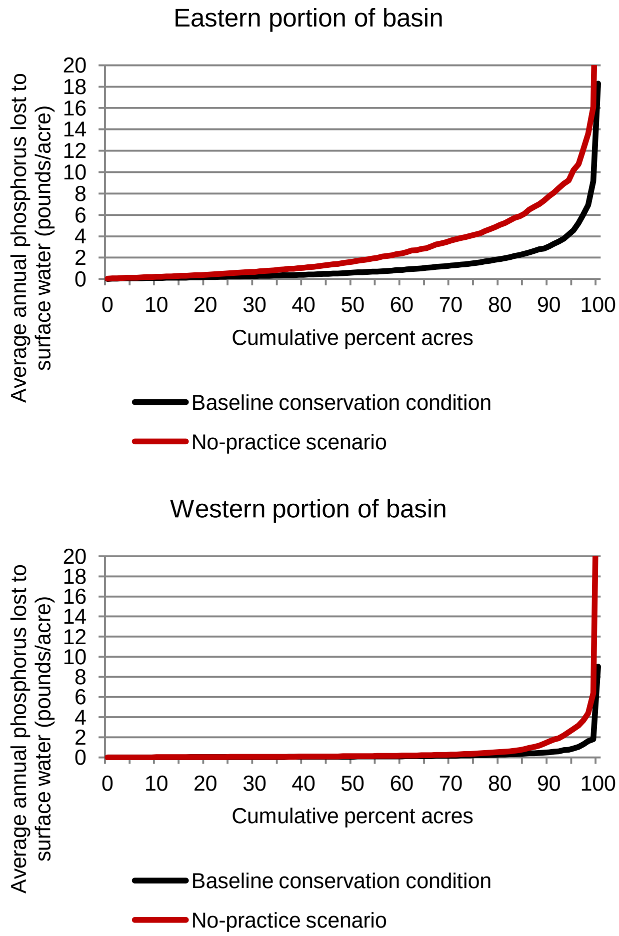


Phosphorus lost to surface water. Phosphorus lost to surface water includes phosphorus lost with waterborne sediment and soluble phosphorus in surface water runoff and in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps, which ultimately contributes to surface water. Phosphorus losses through this pathway are low in the western portion of the basin, but are important in the eastern portion (fig. 54). In the eastern portion of the basin, about 1.25 pounds per acre per year of phosphorus are lost from fields through this pathway—about two-thirds attached to sediment and one-third as soluble phosphorus (table 20).

In the eastern portion of the basin, conservation practice use has reduced phosphorus lost to surface water from cropped acres by an average of 1.76 pounds per acre per year, representing an average reduction of 58 percent (table 20). Without conservation practices, about 26 percent of the cropped acres would have phosphorus lost to surface water in excess of an average of 4 pounds per acre per year, compared to only 6 percent in the baseline (fig. 54). Per-acre reductions are high for some acres in this portion of the basin, as shown in figure 55. About half of the acres have reductions less than 1 pound per acre per year, however.[25]

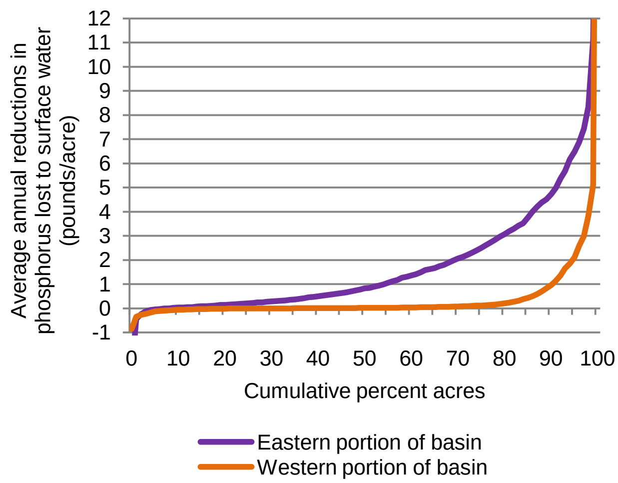
Although losses of phosphorus to surface water are much lower in the western portion of the basin, conservation practices are effective in reducing these losses. In the western portion of the basin, conservation practice use has reduced phosphorus lost to surface water from cropped acres by an average of 0.38 pounds per acre per year, representing an average reduction of 63 percent (table 20).

Figure 54. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble*) for cropped acres in the Missouri River Basin



* Soluble phosphorus lost to surface water includes phosphorus in surface water runoff and in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

Figure 55. Estimates of average annual reduction in phosphorus lost to surface water (sediment attached and soluble) due to conservation practices for cropped acres in the Missouri River Basin



[25] Small negative reductions in surface water runoff, shown in figure 20, also result in small negative reductions in phosphorus lost to surface water for about 1 percent of cropped acres in the region, shown in figure 55.

Land in long-term conserving cover

Conversion of cropped acres to conserving cover eliminates applied phosphorus sources for plant. Phosphorus stored in the soil is brought to the soil surface by plant growth and released through decomposition of the plant material, thereby subjecting the surface phosphorus to the forces of wind and water, resulting in losses of small amounts from fields.

Phosphorus loss from land in long-term conserving cover averages only about 0.07 pound per acre per year in this region, primarily as soluble phosphorus lost to surface water (including lateral subsurface flows) and phosphorus lost with waterborne sediment. Losses are higher in the eastern portion of the basin (0.18 pound per acre per year) than in the western portion (0.03 pound per acre per year) because the higher levels of precipitation in the eastern portion produces more biomass, thus bringing more soil phosphorus to the soil surface through plant uptake decomposition.

Converting cropped acres to long-term conserving cover essentially eliminates phosphorus loss (table 21). Per-acre reductions can be quite high for acres where phosphorus applications are high for the no-practice cropped condition (figs. 56–58 and table 21).

Figure 56. Estimates of average annual reduction in total phosphorus loss due to conversion to long-term conserving cover in the Missouri River Basin

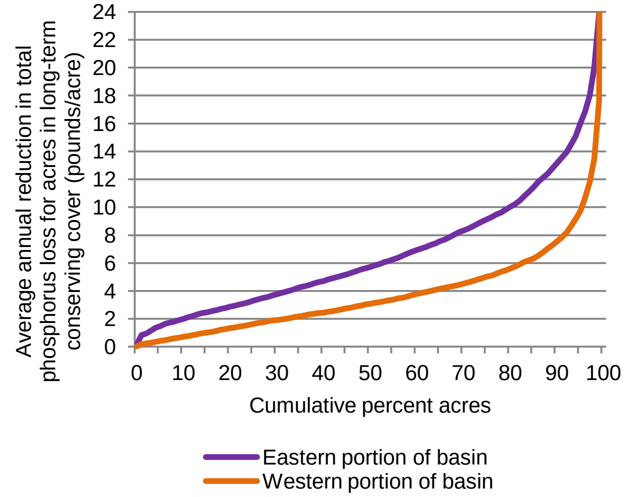


Figure 57. Estimates of average annual reduction in phosphorus lost with windborne sediment due to conversion to long-term conserving cover in the Missouri River Basin

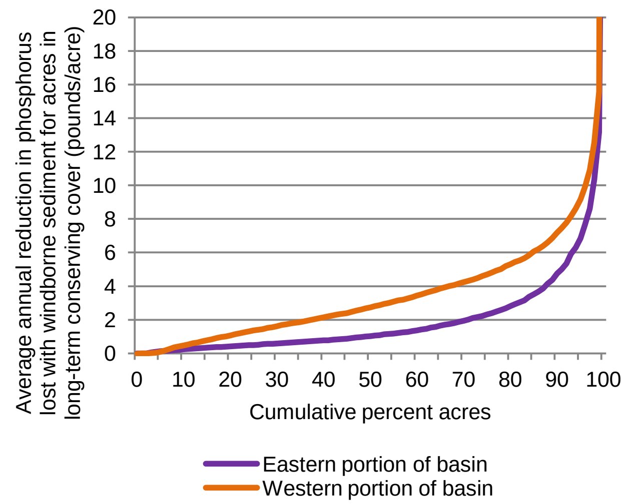


Figure 58. Estimates of average annual reduction in phosphorus lost to surface water due to conversion to long-term conserving cover in the Missouri River Basin

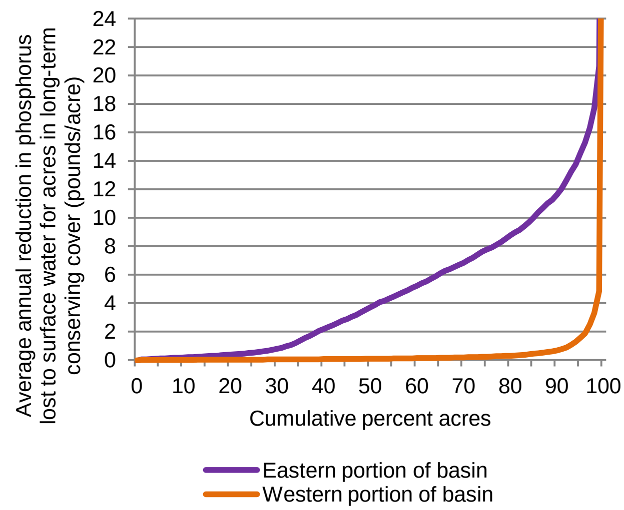


Table 21. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for land in long-term conserving cover (11.2 million acres) in the Missouri River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Average annual values in pounds per acre			
	Entire region			
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	0.0	16.1	16.1	100
Phosphorus in crop yield removed at harvest	0.1**	9.8	9.8	99
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	<0.01	3.14	3.14	100
Phosphorus lost to surface water (sediment attached and soluble)*	0.06	1.84	1.79	97
Soluble phosphorus lost to surface water*	0.03	0.35	0.32	92
Phosphorus loss with waterborne sediment	0.03	1.49	1.46	98
Soluble phosphorus loss to groundwater	<0.01	<0.01	<0.01	1
Total phosphorus loss for all loss pathways	0.07	4.99	4.92	99
Change in soil phosphorus	-0.18	1.17	1.35	--
	Eastern portion of region			
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	0.0	25.5	25.5	100
Phosphorus in crop yield removed at harvest	0.1**	16.4	16.3	99
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	<0.01	2.02	2.02	100
Phosphorus lost to surface water (sediment attached and soluble)*	0.14	5.10	4.95	97
Soluble phosphorus lost to surface water*	0.06	0.87	0.81	93
Phosphorus loss with waterborne sediment	0.08	4.22	4.14	98
Soluble phosphorus loss to groundwater	0.03	0.02	-0.01	-42
Total phosphorus loss for all loss pathways	0.18	7.14	6.96	98
Change in soil phosphorus	-0.40	1.61	2.01	--
	Western portion of basin			
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	0.0	11.9	11.9	100
Phosphorus in crop yield removed at harvest	<0.1**	6.9	6.9	100
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	<0.01	3.64	3.64	100
Phosphorus lost to surface water (sediment attached and soluble)*	0.02	0.39	0.37	95
Soluble phosphorus lost to surface water*	0.01	0.12	0.10	90
Phosphorus loss with waterborne sediment	0.01	0.27	0.26	97
Soluble phosphorus loss to groundwater	<0.01	<0.01	<0.01	76
Total phosphorus loss for all loss pathways	0.03	4.03	4.01	99
Change in soil phosphorus	-0.07	0.98	1.05	--

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.
** Harvest was simulated on acres planted to trees where expected tree age is less than the 47 years included in the model simulation. At tree harvest time, the grass also is removed and replanted.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Effects of Practices on Pesticide Residues and Environmental Risk

Use of pesticides to protect crops from weeds, insects, and diseases is an integral part of crop production. While pesticides are essential for large-scale agriculture, pesticide residues can migrate from the application site and lead to unintentional risk to humans and non-target plants and animals. Most pesticides are applied at much lower rates than nutrients. The fraction of pesticides applied that migrates offsite with water is generally less than 1 to 2 percent. Nevertheless, small amounts of pesticide residue can create water quality concerns depending on the toxicity of the pesticide residues to non-target species and even exceed EPA drinking water standards at times.

Model simulations incorporated pesticide use information from the CEAP survey conducted in 2003–06 (active ingredient, application rate, application method, and time of application).

The effects of converting cultivated cropland to long-term conserving cover were not evaluated for pesticides because the survey did not provide information on pesticide use on land enrolled in CRP General Signups. It was thus assumed that there was no pesticide residues lost from land in long-term conserving cover.

A total of 185 different pesticides are used in the region, as reported in the survey. The most commonly applied pesticides are presented in table 22. The pesticide applied in the largest amount for the entire reigon was glyphosate isopropylamine salt at 36 percent of the total weight of all pesticides applied, followed by atrazine at 18 percent, acetochlor at 9 percent, and S-metolachlor at 4 percent. These four herbicides accounted for 69 percent of the pesticides applied in the region, by weight.

The quantity of pesticides applied is higher in the eastern portion of the basin (58 percent of the quantity of all pesticide applied) than in the western portion.

Table 22. Pesticides most commonly used in the Missouri River Basin

Pesticide (active ingredient name)	Pesticide type	Percent of the total amount of pesticides applied (by weight) in the Missouri River basin
Eastern portion of the basin		
Glyphosate, isopropylamine salt	Herbicide	22.8
Atrazine	Herbicide	11.6
Acetochlor	Herbicide	7.5
S-Metolachlor	Herbicide	3.6
Metolachlor	Herbicide	1.5
Trifluralin	Herbicide	1.1
Pendimethalin	Herbicide	1.1
Alachlor	Herbicide	0.8
Glyphosate-trimesium	Herbicide	0.8
Glyphosate	Herbicide	0.5
2,4-D, 2-ethylhexyl ester	Herbicide	<0.5
2,4-Dichlorophenoxyacetic acid	Herbicide	<0.5
2,4-D, dimethylamine salt	Herbicide	<0.5
Subtotal		52.0
Western portion of the basin		
Glyphosate, isopropylamine salt	Herbicide	13.3
Atrazine	Herbicide	6.8
1,3-Dichloropropene	Fungicide	2.5
S-Metolachlor	Herbicide	2.2
2,4-D, 2-ethylhexyl ester	Herbicide	1.7
2,4-Dichlorophenoxyacetic acid	Herbicide	1.5
Acetochlor	Herbicide	1.1
2,4-D, dimethylamine salt	Herbicide	1.1
Metolachlor	Herbicide	1.0
Trifluralin	Herbicide	0.9
Glyphosate	Herbicide	0.6
Alachlor	Herbicide	0.5
Glyphosate-trimesium	Herbicide	0.5
Pendimethalin	Herbicide	<0.5
Subtotal		33.9
Total*		85.9

* Pesticides not listed each represented less than 1 percent of the total applied in the entire region. Percents may not add to total due to rounding.

Baseline condition for pesticide loss

The APEX model tracks the mass loss for three pesticide loss pathways: [26]

- pesticides dissolved in surface water runoff,
- pesticides adsorbed to sediment lost through water erosion, and
- pesticides dissolved in subsurface flow pathways, which include surface and tile drainage systems, lateral subsurface flow, and percolation through the root zone.

All three pathways are important in the transport of pesticide residues from fields in this region, but the majority of pesticide mass loss (61 percent) is dissolved in surface water runoff. Pesticides lost with waterborne sediment accounted for about 24 percent, and pesticides in subsurface flows accounted for 15 percent. The highest losses are in the eastern portion of the basin for all three loss pathways (fig. 59).

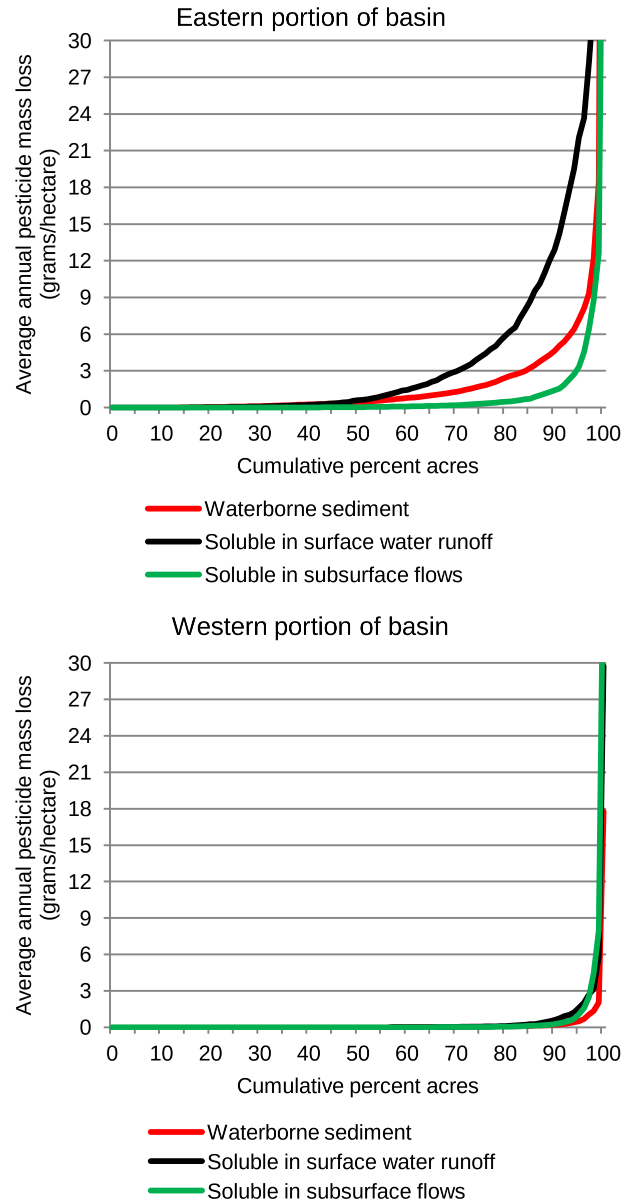
Overall, loss of pesticides from fields in the eastern portion of the basin accounted for 87 percent of the total mass loss of all pesticides in the region. In this portion of the basin, the dominant pesticide loss pathway for 50 percent of cropped acres was pesticides dissolved in surface water runoff. Pesticide loss with waterborne sediment was the dominant loss pathway for 37 percent of cropped acres, and soluble pesticide loss in subsurface flow was the dominant loss pathway for 9 percent. About 4 percent of cropped acres had no pesticide losses in this portion of the basin. (The dominant loss pathway was determined for each sample point as the pathway with the highest pesticide mass loss.)

About 90 percent of the cropped acres in the western portion of the basin had negligible amounts of pesticide loss from farm fields, as shown in figure 59. About 12 percent of cropped acres had no pesticide loss in this portion of the basin.

The most common pesticide residues lost from farm fields in the Missouri River Basin are presented in table 23. For the entire reigon, six herbicides account for 84 percent of all pesticide residues lost from fields in the model simulations—atrazine (43 percent of total mass loss), glyphosate isopropylamine salt (14 percent), acetochlor (9 percent), S-metolachlor (9 percent), metolachlor (6 percent), and sulfentrazone (5 percent).

The average annual amount of pesticide lost from farm fields in the Missouri River Basin is about 3.4 grams of active ingredient per hectare per year (table 24).[27] As shown in figure 59, however, per-hectare losses are much higher than the average loss for a minority of acres within the Missouri River Basin (fig. 59).

Figure 59. Estimates of average annual pesticide loss (mass loss of all pesticides combined) for three loss pathways, Missouri River Basin, baseline conservation condition



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[26] The APEX model currently does not estimate pesticides lost in spray drift, volatilization, or with windblown sediment.

[27] Grams per hectare is the standard reporting unit for pesticide active ingredients.

Table 23. Most common pesticides contributing to losses from farm fields, Missouri River Basin

Pesticide (active ingredient name)	Pesticide type	Percent of total pesticide mass loss from fields in the Missouri River basin
Eastern portion of the basin		
Atrazine	Herbicide	37.0
Glyphosate, isopropylamine salt	Herbicide	12.3
Acetochlor	Herbicide	9.2
S-Metolachlor	Herbicide	7.7
Metolachlor	Herbicide	4.7
Sulfentrazone	Herbicide	3.9
Alachlor	Herbicide	1.5
Flufenacet	Herbicide	1.3
Dimethenamide-P	Herbicide	0.9
Simazine	Herbicide	0.8
Pendimethalin	Herbicide	0.7
Subtotal		80.0
Western portion of the basin		
Atrazine	Herbicide	5.6
Glyphosate, isopropylamine salt	Herbicide	1.3
S-Metolachlor	Herbicide	1.0
Metolachlor	Herbicide	0.9
Sulfentrazone	Herbicide	0.6
Acetochlor	Herbicide	<0.5
Flufenacet	Herbicide	<0.5
Alachlor	Herbicide	<0.5
Pendimethalin	Herbicide	<0.5
Subtotal		9.9
Total**		89.9

** Pesticides not listed each represented less than 1 percent of the total loss in the entire region. Percents may not add to total due to rounding.

Table 24. Field-level effects of conservation practices on pesticide loss and associated edge-of-field environmental risk for cropped acres in the Missouri River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
		Entire region		
Pesticide sources				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,027	1,196	169	14
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	3.4	6.3	2.9	46
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	1.33	3.75	2.41	64
Average annual surface water pesticide risk indicator for humans	0.26	0.48	0.22	45
Average annual groundwater pesticide risk indicator for humans	0.06	0.08	0.02	23
		Eastern portion of basin		
Pesticide sources				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,372	1,649	277	17
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	6.7	11.5	4.8	41
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	1.58	2.70	1.12	41
Average annual surface water pesticide risk indicator for humans	0.35	0.53	0.18	35
Average annual groundwater pesticide risk indicator for humans	0.07	0.09	0.02	24
		Western portion of basin		
Pesticide sources				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	762	847	85	10
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	0.8	2.3	1.5	66
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	1.14	4.55	3.41	75
Average annual surface water pesticide risk indicator for humans	0.20	0.44	0.24	54
Average annual groundwater pesticide risk indicator for humans	0.05	0.07	0.02	22

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 29 subregions.

Effects of conservation practices on pesticide residues and risk

Management practices that reduce the potential for loss of pesticides from farm fields consist of a combination of Integrated Pest Management (IPM) techniques and water erosion control practices. Water erosion control practices mitigate the loss of pesticides from farm fields by reducing surface water runoff and sediment loss, both of which carry pesticide residues from the farm field to the surrounding environment. IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environmental condition. IPM consists of a management strategy for prevention, avoidance, monitoring, and suppression of pest populations. When the use of pesticides is necessary to protect crop yields, selection of pesticides that have the least environmental risk is an important aspect of the suppression component of IPM.

Model simulations show that conservation practices—primarily water erosion control practices—are effective in reducing the loss of pesticide residues from farm fields. Use of conservation practices has reduced the loss of pesticides (summed over all pesticides) in the region by an average of 2.9 grams of active ingredient per hectare per year, representing a 46-percent reduction from the 6.3 grams per hectare for the no-practice scenario (table 24). In the eastern portion, pesticide loss has been reduced by an average of 4.8 grams of active ingredient per hectare per year (41-percent reduction), compared to a reduction of 1.5 grams per acre per year in the western portion (66-percent reduction).

However, the total quantity of pesticide residues lost from the field is not the most useful outcome measure for assessing the environmental benefits of conservation practices on reducing pesticide residues. The environmental impact of pesticide residues is specific to the toxicity of each pesticide to the non-target species that may be exposed to the pesticide. For example, some pesticides used in large quantities, such as glyphosate, have relatively low toxicity thresholds for most non-target species.

Pesticide risk indicators were therefore developed to represent risk at the edge of the field (bottom of soil profile for groundwater) and for aggregating pesticide risk over the 185 pesticides included in the model for this region.[28] These edge-of-field risk indicators are based on the ratio of pesticide concentrations in water leaving the field to safe concentrations (toxicity thresholds) for each pesticide. As such, these risk indicators do not have units. Risk indicator values of less than 1 are considered "safe" because the concentration is below the toxicity threshold for exposure at the edge of the field.[29]

Three edge-of-field risk indicators are used here to assess the effects of conservation practices: (1) surface water pesticide risk indicator for aquatic ecosystems, (2) surface water pesticide risk indicator for humans, and (3) groundwater pesticide risk indicator for humans. The surface water risk indicator includes pesticide residues in solution in surface water runoff and in all subsurface water flow pathways that eventually return to surface water (water flow in a surface or tile drainage system, lateral subsurface water flow, and groundwater return flow). The pesticide risk indicator for aquatic ecosystems was based on chronic toxicities for fish and aquatic invertebrates, and acute toxicities for algae and vascular aquatic plants. The pesticide risk indicators for humans were based on drinking water standards or the equivalent for pesticides where standards have not been set.

These indicators provide a consistent measure that is comparable from field to field and that represents the effects of farming activities on risk reduction without being influenced by other landscape factors. In most environmental settings, however, non-target species are exposed to concentrations that have been diluted by water from other sources, even when those environments are located adjacent to a field. Consequently, these edge-of-field risk indicators cannot be used to predict actual environmental impacts.

Figure 60 shows that for most years the overall risk for aquatic ecosystems is low, in part because of the conservation practices in use. Over 80 percent of cropped acres in this region have aquatic ecosystem risk indicator scores below 1 in all years. But in some years the edge-of-field concentrations can be high relative to toxicity thresholds.

The pesticide risk indicator for aquatic ecosystems averaged 1.33 over all years and cropped acres for the baseline conservation condition (table 24). The 1.33 value indicates that pesticide concentrations in water leaving cropped fields in the Missouri River Basin are, on average, 1.33 times the "safe" concentration for non-target plant and animal species when exposed to concentrations at the edge of the field.

The two pesticide risk indicators for humans are much lower than for the aquatic ecosystem, averaging only 0.26 for surface water and 0.06 for groundwater (table 24).

Atrazine was the dominant pesticide contributing to all three risk indicators (table 25). Based on the model simulations, the edge-of-field risk indicator for atrazine exceeded 1 for 14 percent of the cropped acres for risk to aquatic ecosystems, 6 percent of the cropped acres for surface water risk to humans, and 1 percent of the cropped acres for groundwater risk to humans.

Atrazine's dominance in the risk indicators is due to its widespread use, its mobility (solubility = 30 mg/L; Koc = 100 g/ml), its persistence (field half-life = 60 days), its toxicity to aquatic ecosystems (aquatic plant toxicity = 1 ppb), and the human drinking water standard (EPA Maximum Contaminant Level = 3 ppb).

[28] For a complete documentation of the development of the pesticide risk indicators, see "Pesticide risk indicators used in the CEAP cropland modeling," found at http://www.nrcs.usda.gov/technical/nri/ceap.

[29] A threshold value of 1 for the pesticide risk indicator applies when assessing the risk for a single pesticide. Since the indicator is summed over all pesticides in this study, a threshold value of 1 would still apply if pesticide toxicities are additive and no synergistic or antagonistic effects are produced when non-target species are exposed to a mix of pesticides.

Pesticide Risk Indicators

Three ***edge-of-field*** pesticide risk indicators were used to assess the effects of conservation practices:

1. surface water pesticide risk indicator for aquatic ecosystems,
2. surface water pesticide risk indicator for humans, and
3. groundwater pesticide risk indicator for humans.

Pesticide risk indicators were calculated for each pesticide as the ratio of the concentration in water leaving the field to the "safe" concentration (toxicity thresholds) for each pesticide, where both are expressed in units of parts per billion. This ratio is called the Aquatic Risk Factor (ARF). ARFs are unit-less numbers that represent the relative toxicity of pesticides in solution. A risk indicator value of less than 1 is considered "safe" because the concentration is below the toxicity threshold for exposure at the edge-of-the field.

$$\text{ARF} = \frac{\text{(Annual Concentration)}}{\text{(Toxicity Threshold)}} < 1 \quad \rightarrow \text{Little or no potential adverse impact}$$

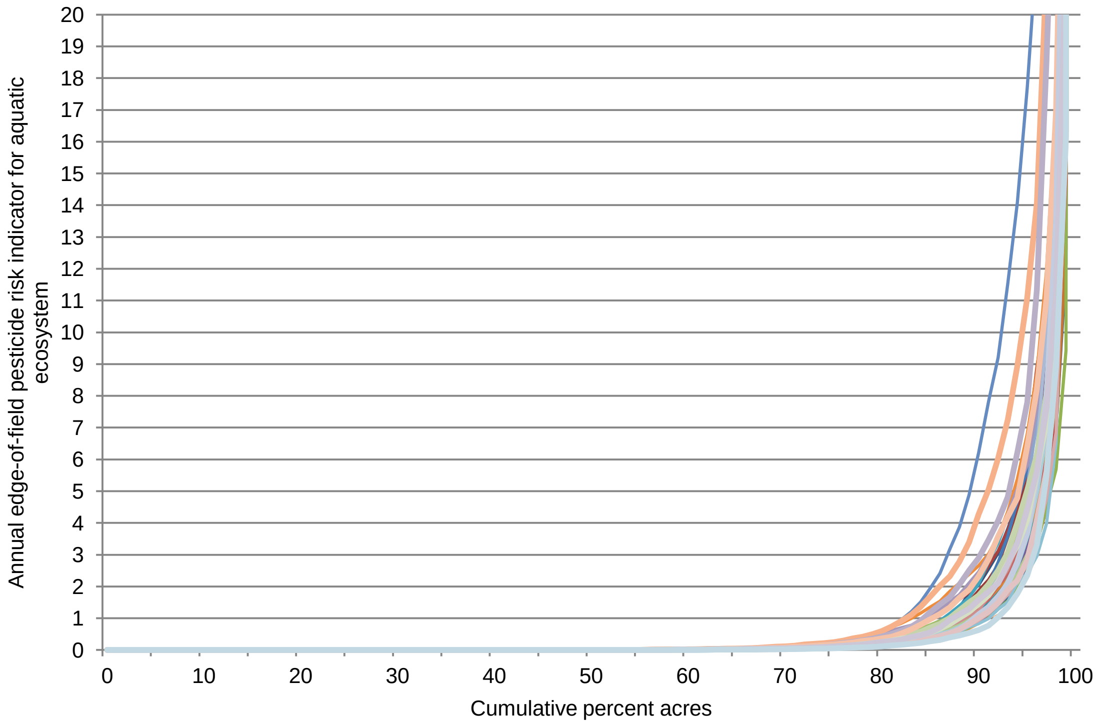
Two aquatic toxicity thresholds were used in estimating potential risk:

- Human drinking water lifetime toxicity thresholds. These thresholds are either taken from the EPA Office of Water Standards, or derived from EPA Reference Doses or Cancer Slopes using the methods employed by the EPA Office of Water.
- Aquatic ecosystem toxicity thresholds. The lowest (most sensitive) toxicity is used from the fish chronic NOEL (No Observable Effect Concentration), invertebrate chronic NOEL, aquatic vascular plant acute EC50 (Effective Concentration that is lethal to 50 percent of the population) and aquatic nonvascular plant acute EC50.

Table 25. Dominant pesticides determining edge-of-field environmental risk, Missouri River Basin

Pesticide (active ingredient name)	Pesticide type	Percent of cropped acres in the region with average annual edge-of-field risk indicator greater than 1
Risk indicator for aquatic ecosystem		
Atrazine	Herbicide	14.2
2,4-D, 2-ethylhexyl ester	Herbicide	2.5
Acetochlor	Herbicide	2.1
Metolachlor	Herbicide	1.6
Sulfentrazone	Herbicide	1.6
Phostebupirim	Insecticide	1.1
All other pesticides	--	2.1
Risk indicator for humans, surface water		
Atrazine	Herbicide	5.7
All other pesticides	--	0.5
Risk indicator for humans, groundwater		
Atrazine	Herbicide	0.9
All other pesticides	--	0.1

Figure 60. Distribution of annual values of the edge-of-field surface water pesticide risk indicator for aquatic ecosystems for each year of the 47-year model simulation, baseline conservation condition, Missouri River Basin



Note: This figure shows how the annual values of the risk indicator varied within the region and from year to year in the model simulation on cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual values of the risk indicator varied over the region in that year, starting with the acres with the lowest value and increasing to the acres with the highest value. The family of curves shows how annual values vary from year to year.

Pesticide risk indicators are relatively low in this region because overall pesticide use is relatively low, compared to other regions, and because of the mitigating effects of conservation practice use, primarily soil erosion control practices and IPM.

The use of conservation practices has reduced the pesticide risk indicator for aquatic ecosystems by 64 percent for the region (41 percent for the eastern portion and 75 percent for the western portion) (table 24, fig. 61). The surface water pesticide risk indicator for humans has been reduced by an average of 45 percent (35 percent for the eastern portion and 54 percent for the western portion) (table 24, fig. 62). The groundwater pesticide risk indicator for humans, which is very low in both regions, has been reduced by an average of 23 percent (table 24).

Figure 63 shows the distribution of the reductions in the two pesticide risk indicators due to conservation practices. Significant risk reductions for aquatic ecosystems occur on about 15 percent of the acres, while significant risk reductions for humans occur on only about 5 percent of the acres.[30] The benefits of conservation practices were significant for both aquatic risks and human risks on the acres that had those risks, but aquatic risks were more widespread than human risks so conservation practices have greater total benefit for aquatic ecosystems than for human drinking water.

[30] Small negative reductions in surface water runoff, shown in figure 20, also result in small negative reductions in pesticide risk indicators, shown in figure 63. Small negative reductions can also occur on these landscapes as a result of reduced tillage.

Figure 61. Estimates of average annual edge-of-field surface water pesticide risk indicator for aquatic ecosystems, Missouri River Basin

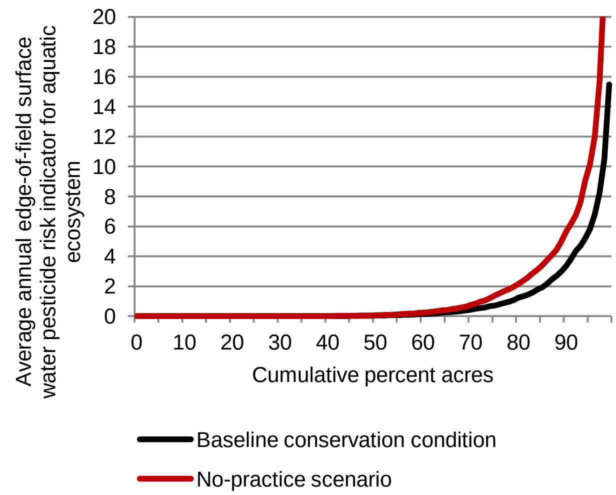


Figure 62. Estimates of average annual edge-of-field surface water pesticide risk indicator for humans, Missouri River Basin

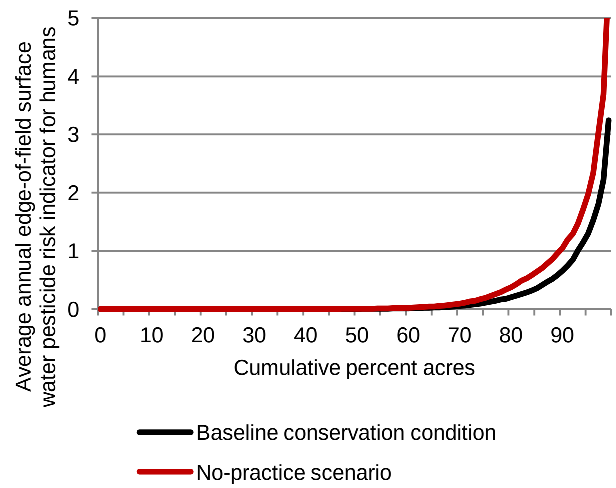
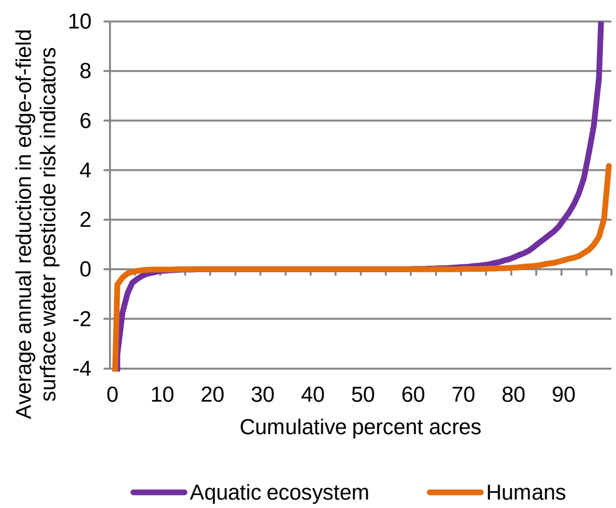


Figure 63. Estimates of average annual reductions in the edge-of-field surface water pesticide risk indicators for aquatic ecosystems in the Missouri River Basin



Chapter 5
Assessment of Conservation Treatment Needs

The adequacy of conservation practices in use in the Missouri River Basin was evaluated to identify remaining conservation treatment needs for controlling wind and water erosion and nutrient loss from fields. The evaluation was based on conservation practice use for the time period 2003 through 2006.

In summary, findings for the Missouri River Basin indicate that—

- *1 percent of cropped acres (1.1 million acres) have a* ***high*** *level of need for additional conservation treatment,*
- *17 percent of cropped acres (14.2 million acres) have a* ***moderate*** *level of need for additional conservation treatment, and*
- *82 percent of cropped acres (68.3 million acres) have a* ***low*** *level of need for additional treatment and are considered to be adequately treated.*

The 15.3 million acres with additional conservation treatment needs—under-treated acres—were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Derivation of conservation treatment levels and inherent soil vulnerability classes are described in the next two sections, followed by estimates of under-treated acres.

Field-level model simulation results for the baseline conservation condition were used to make the assessment. Five resource concerns were evaluated for the Missouri River Basin:

1. Sediment loss due to water erosion
2. Nitrogen loss with surface runoff (nitrogen attached to sediment and in solution)
3. Nitrogen loss in subsurface flows
4. Phosphorus lost to surface water (phosphorus attached to sediment and in solution, including soluble phosphorus in subsurface lateral flow pathways)
5. Wind erosion

The identification of conservation treatment needs was done separately for the eastern and western portions of the basin to better account for the differences in precipitation, land use, use of conservation practices, and resource concerns within the basin.

The conservation treatment needs for controlling pesticide loss were not evaluated because the assessment requires information on pest infestations, which was not available for the CEAP sample points. A portion of the pesticide residues are controlled by soil erosion control practices; meeting soil erosion control treatment needs would provide partial protection against loss of pesticide residues from farm fields. Integrated Pest Management (IPM) practices are also effective in reducing the risk associated with pesticide residues leaving the farm field. Determination of adequate IPM, however, is highly dependent on the specific site conditions and the nature and extent of the pest problems.

Adequate conservation treatment consists of combinations of conservation practices that treat the specific inherent vulnerability factors associated with each field. Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres to reduce field-level losses to acceptable levels. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Conservation Treatment Levels

Drawing from the evaluation of practice use presented in chapter 3, four levels of conservation treatment (high, moderately high, moderate, and low) were defined for each of the five resource concerns. A “high” level of treatment was shown by model simulations (see chapter 6) to reduce sediment and nutrient losses to low levels for nearly all cropped acres in the Missouri River Basin.

For sediment loss due to water erosion, conservation treatment levels were defined by a combination of structural practices and residue and tillage management practices, as defined in figure 64. A high level of water erosion control treatment is in use on about 27 percent of cropped acres, mostly in the eastern portion of the basin. About 43 percent of cropped acres have a moderate level of conservation treatment for water erosion control, most of which are in the western portion of the basin.

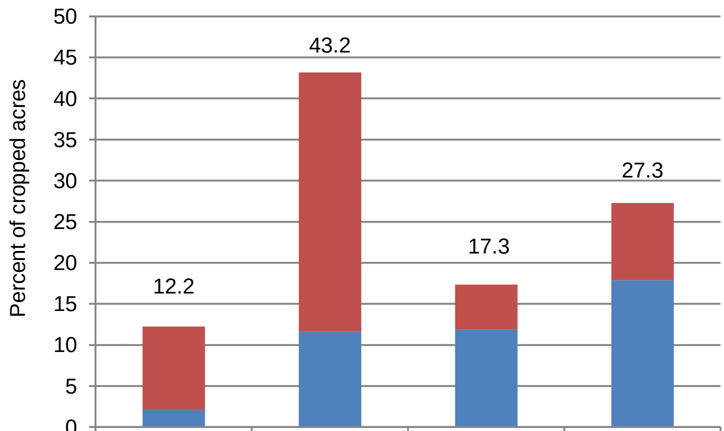
For nitrogen loss with surface runoff, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and nitrogen management practices, as defined in figure 65. A high level of treatment for nitrogen runoff is in use on only 5 percent of cropped acres. The bulk of cropped acres—91 percent—have combinations of practices that indicate a moderately high or moderate level of treatment. About 4 percent of cropped acres have a low level of treatment for nitrogen runoff, most of which are in the western portion of the basin.

For phosphorus lost to surface water, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and phosphorus management practices, as defined in figure 66. A high level of treatment for phosphorus runoff is in use on 14 percent of the acres, most of which are in the eastern portion of the basin. About 78 percent of cropped acres have combinations of practices that indicate a moderately high or moderate level of treatment. Only 8 percent of cropped acres have a low level of phosphorus management, most of which are in the western portion of the basin.

The nitrogen management level presented in figure 11 (see chapter 3) was used to evaluate the adequacy of conservation treatment for nitrogen loss in subsurface flows. A high level of treatment for nitrogen loss in subsurface flows is in use on 30 percent of the acres, most of which are in the western portion of the basin. About 63 percent of cropped acres have combinations of practices that indicate a moderately high or moderate level of treatment. Only 7 percent of cropped acres have a low level of nitrogen management, most of which are in the eastern portion of the basin.

For wind erosion, a combination of structural practices and tillage intensity was used to evaluate the adequacy of conservation treatment, as defined in figure 67. A high level of treatment for wind erosion is in use on 8 percent of the acres. About 86 percent of the acres have a moderately high or moderate level of treatment. Only 6 percent of the acres have a low level of treatment for controlling wind erosion.

Figure 64. Percent of cropped acres at four conservation treatment levels for water erosion control in the baseline conservation condition, Missouri River Basin



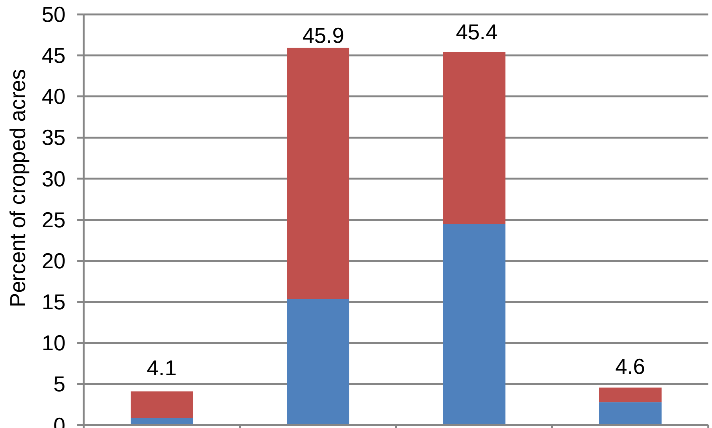
	Low	Moderate	Moderately high	High
Western portion of basin	10.2	31.5	5.4	9.4
Eastern portion of basin	2.1	11.6	11.9	17.9

Criteria for water erosion control treatment levels were derived using a combination of structural practice treatment levels and residue and tillage management treatment levels. Scores were first assigned to each of these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1 (see figs. 9 and 10). If slope was 2 percent or less, the water erosion control treatment level is the same as the residue and tillage management level. If slope was greater than 2 percent, the water erosion control treatment level is determined as follows:

- **High treatment**: Sum of scores is equal to 8. (High treatment level for both structural practices and residue and tillage management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.

Figure 65. Percent of cropped acres at four conservation treatment levels for nitrogen runoff control in the baseline conservation condition, Missouri River Basin



	Low	Moderate	Moderately high	High
Western portion of basin	3.2	30.6	20.9	1.8
Eastern portion of basin	0.9	15.4	24.5	2.8

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and nitrogen management treatment levels. Scores were first assigned to each of these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1 (see figs. 9-11).

If slope was 2 percent or less, the nitrogen runoff control treatment level is determined as follows:

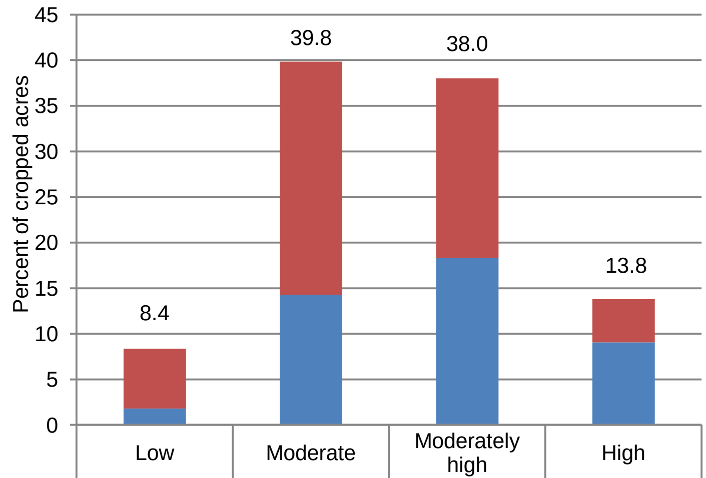
- **High treatment**: Sum of residue and tillage management score and nitrogen management score is equal to 8. (High treatment level for both structural practices and nitrogen management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the nitrogen runoff control treatment level is determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and nitrogen management score is equal to 12. (High treatment level for all three treatment types.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.

Figure 66. Percent of cropped acres at four conservation treatment levels for phosphorus runoff control in the baseline conservation condition, Missouri River Basin



	Low	Moderate	Moderately high	High
Western portion of basin	6.5	25.6	19.7	4.7
Eastern portion of basin	1.8	14.3	18.3	9.1

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and phosphorus management treatment levels (see figs. 9, 10, and 12) in the same manner as the nitrogen runoff control treatment level. Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1.

If slope was 2 percent or less, the phosphorus runoff control treatment level is determined as follows:

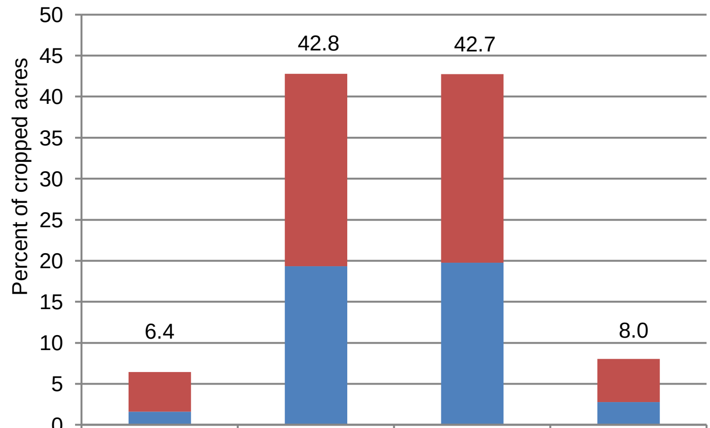
- **High treatment**: Sum of residue and tillage management score and phosphorus management score is equal to 8. (High treatment level for both structural practices and phosphorus management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the phosphorus runoff control treatment level is determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and phosphorus management score is equal to 12. (High treatment level for all three treatment types.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.

Figure 67. Percent of cropped acres at four conservation treatment levels for wind erosion management, baseline conservation condition, Missouri River Basin



	Low	Moderate	Moderately high	High
Western portion of basin	4.8	23.5	23.0	5.3
Eastern portion of basin	1.6	19.3	19.7	2.8

Criteria were derived using a combination of structural practices for wind erosion control and residue and tillage management. Criteria for four levels of treatment are:

- **High treatment**: *All crops* meet tillage intensity criteria for either no-till or mulch till and at least one wind erosion control structural practice is in use.
- **Moderately high treatment**: A*ll crops* meet tillage intensity criteria for either no-till or mulch till without any wind erosion control structural practice <u>or</u> a*verage annual* tillage intensity meets criteria for mulch till or no-till and a wind erosion control structural practice is in use.
- **Moderate treatment**: A*verage annual* tillage intensity meets criteria for mulch till or no-till without any wind erosion control structural practice in use.
- **Low treatment**: No wind erosion control structural practices and *average annual* tillage intensity meets criteria for mulch till or no-till.

Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.

Inherent Vulnerability Factors

Not all acres require the same level of conservation treatment because of differences in inherent vulnerabilities due to soils and climate. Inherent vulnerability factors for surface runoff include soil properties that promote surface water runoff and erosion—soil hydrologic group, slope, and soil erodibility (the water erosion equation K-factor). Inherent vulnerability factors for loss of nutrients in subsurface flows include soil properties that promote infiltration—soil hydrologic group, slope, water erosion equation K-factor, and coarse fragment content of the soil. Because the vulnerability indicators are based on soils characteristics, they are referred to as "soil vulnerability potentials."

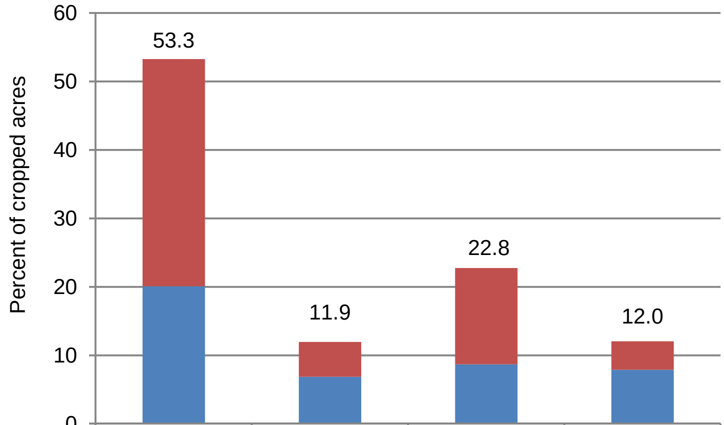
Soil runoff and leaching potentials were estimated for each sample point on the basis of vulnerability criteria. A single set of criteria was developed for all regions and soils in the United States to allow for regional comparisons. Thus, some soil vulnerability potentials are not well represented in every region.

The criteria for the soil runoff potential are presented in figure 68, followed by the spatial distribution of the soil runoff potential within the Missouri River Basin in figure 69. The criteria and spatial distribution for the soil leaching potential are presented in figures 70 and 71. The criteria for the soil wind erosion potential are presented in figures 72 and 73. The maps show the vulnerability potentials for all soils and land uses in the region. For the assessment of conservation treatment needs, however, only the vulnerability potentials for cropped acres were used.

Cropped acres in the Missouri River Basin generally have low soil vulnerability potential. Nonetheless, a significant percentage of acres have either a high or moderately high vulnerability to one or more of the three vulnerability potentials.

- The majority of cropped acres have a low soil runoff potential (fig. 68). Twelve percent of the acres have a high soil runoff potential, mostly in the eastern portion of the basin, and 23 percent have a moderately high soil runoff potential, mostly in the western portion of the basin.
- Few cropped acres in this region have a high or moderately high soil leaching potential—11 percent (fig. 70); most of these acres are in the western portion of the basin. The bulk of cropped acres—78 percent—has a moderate soil leaching potential. The remaining 11 percent have a low soil leaching potential.
- While less than 2 percent of cropped acres have a high inherent potential for wind erosion based on soil properties and precipitation (fig. 72), about 26 percent of cropped acres have a moderately high potential. Nearly all of these acres are in the western portion of the basin.

Figure 68. Soil runoff potential for cropped acres in the Missouri River Basin



	Low	Moderate	Moderately high	High
Western portion of basin	33.2	5.1	14.1	4.2
Eastern portion of basin	20.1	6.9	8.7	7.9

Criteria for four classes of soil runoff potential were derived using a combination of soil hydrologic group, percent slope, and K-factor, as shown in the table below:

Soil runoff potential	Acres with soil hydrologic group A	Acres with soil hydrologic group B	Acres with soil hydrologic group C	Acres with soil hydrologic group D
Low	All acres	Slope<4	Slope<2	Slope<2 and K-factor<0.28
Moderate	None	Slope >=4 and <=6 and K-factor<0.32	Slope >=2 and <=6 and K-factor<0.28	Slope<2 and K-factor>=0.28
Moderately high	None	Slope >=4 and <=6 and K-factor>=0.32	Slope >=2 and <=6 and K-factor>=0.28	Slope >=2 and <=4
High	None	Slope>6	Slope>6	Slope>4

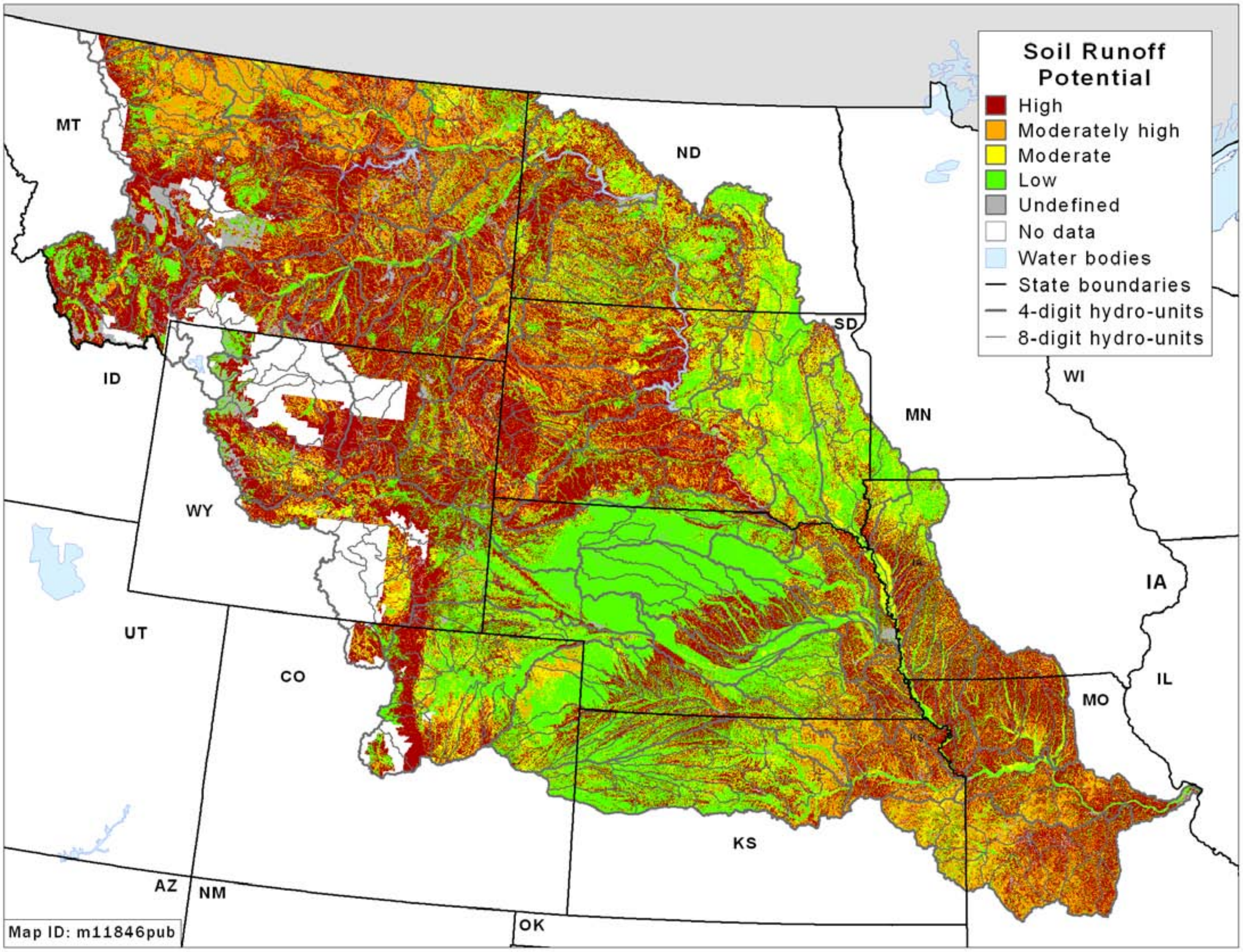
Hydrologic soil groups are classified as:

- **Group A—**sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- **Group D**—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.

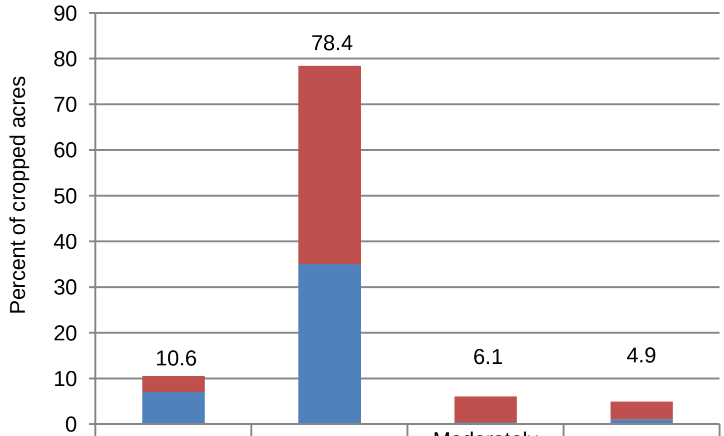
Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.
Note: See appendix B, table B4, for a breakdown of soil runoff potential by subregion.

Figure 69. Soil runoff potential for soils in the Missouri River Basin



Note: The soil runoff potential shown in this map was derived using the criteria presented in figure 68 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 70. Soil leaching potential for cropped acres in the Missouri River Basin



	Low	Moderate	Moderately high	High
Western portion of basin	3.5	43.4	5.7	3.9
Eastern portion of basin	7.1	35.0	0.4	1.1

Criteria for four classes of soil leaching potential were derived using a combination of soil hydrologic group, percent slope, and K-factor, as shown in the table below:

Soil leaching potential	Acres with soil hydrologic group A	Acres with soil hydrologic group B	Acres with soil hydrologic group C	Acres with soil hydrologic group D
Low	None	None	None	All acres except organic soils
Moderate	None	Slope <=12 and K-factor>=0.24 or slope>12	All acres except organic soils	None
Moderately high	Slope>12	Slope >=3 and <=12 and K-factor<0.24	None	None
High	Slope<=12 or acres classified as organic soils	Slope<3 and K-factor <0.24 or acres classified as organic soils	Acres classified as organic soils	Acres classified as organic soils

Coarse fragments (stones and rocks) in the soil make it easier for water to infiltrate rather than run off. If the coarse fragment content of the soil was greater than 30 percent, the soil leaching potential was increased two levels (moderate and moderately high to high, and low to moderately high). If the coarse fragment content was greater than 10 percent but less than 30 percent, the soil leaching potential was increased one level.

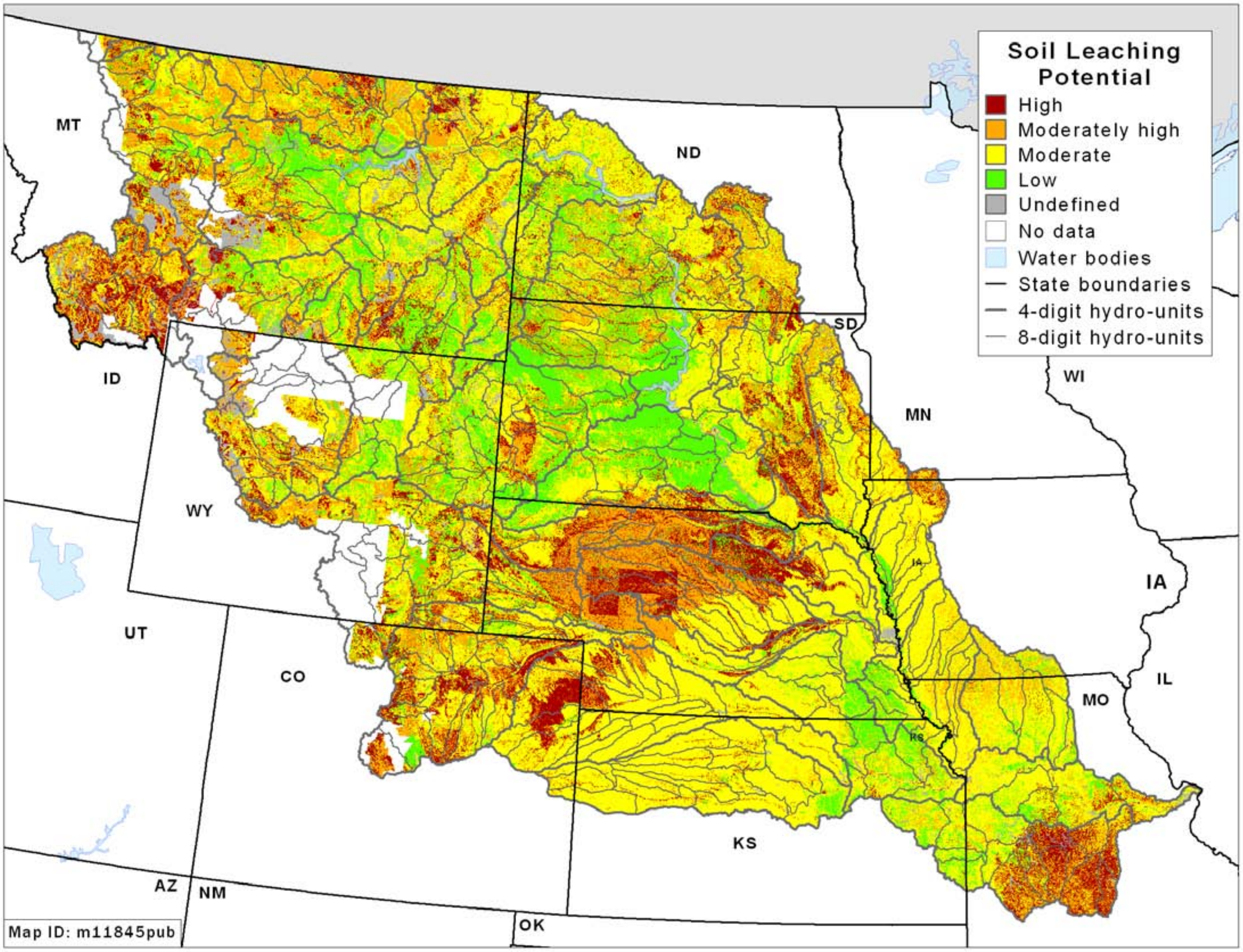
Hydrologic soil groups are classified as:

- **Group A—**sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- **Group D**—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

Note: K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.

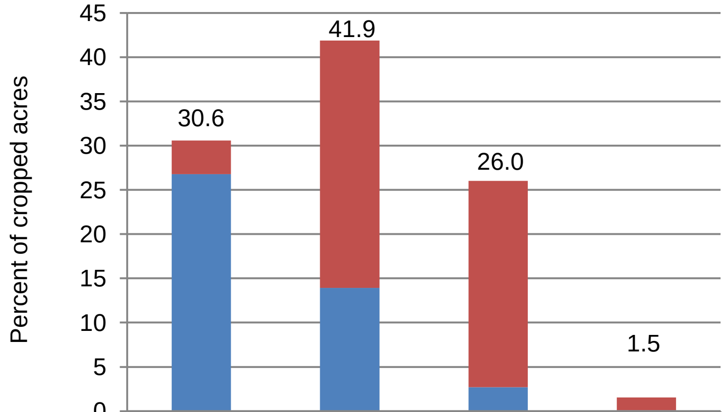
Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.
Note: See appendix B, table B4, for a breakdown of soil leaching potential by subregion.

Figure 71. Soil leaching potential for soils in the Missouri River Basin



Note: The soil leaching potential shown in this map was derived using the criteria presented in figure 70 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 72. Soil wind erosion potential for cropped acres in the Missouri River Basin



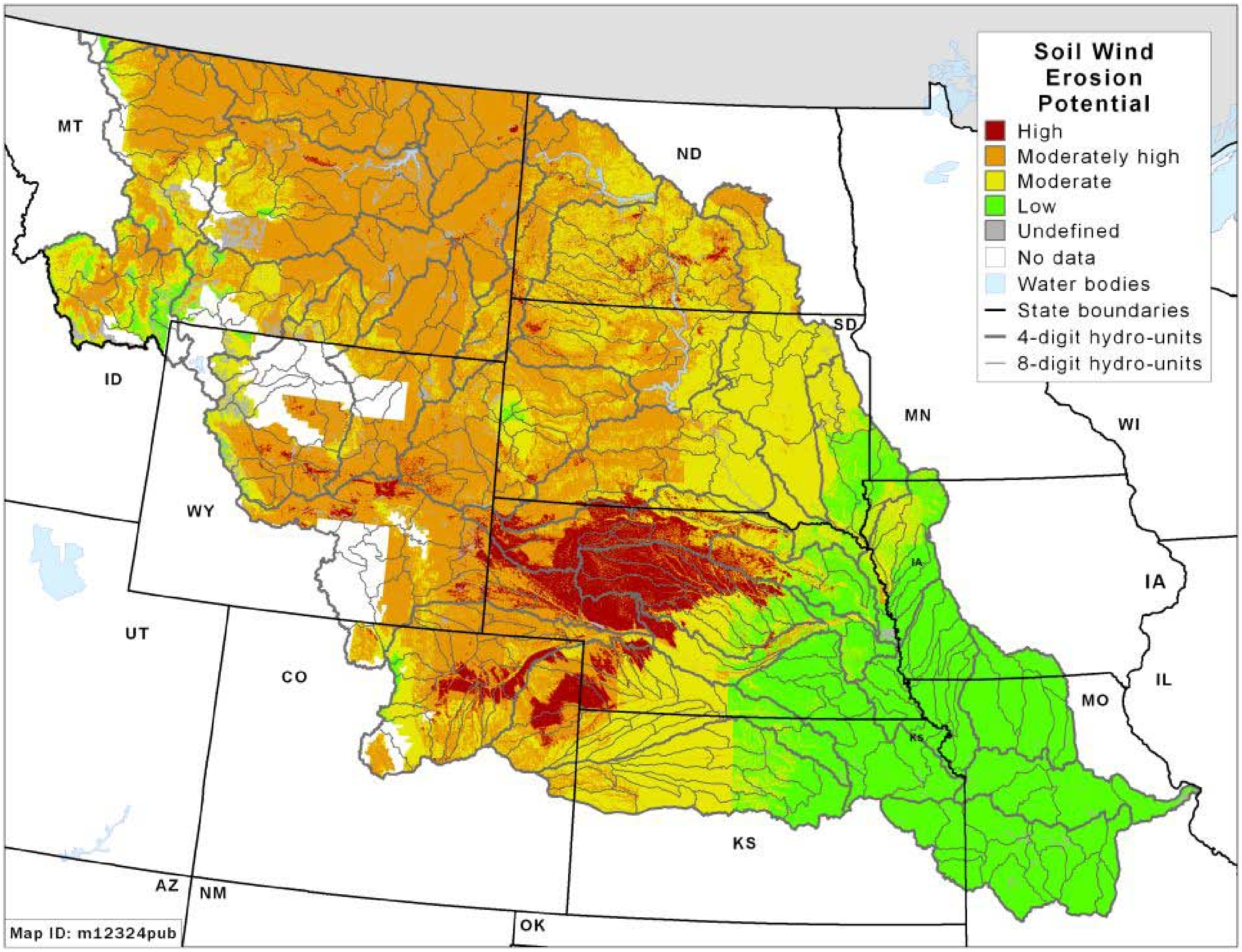
	Low	Moderate	Moderately high	High
Western portion of basin	3.8	27.9	23.3	1.4
Eastern portion of basin	26.8	13.9	2.7	0.1

Criteria for four classes of wind erosion potential were derived using a combination of annual precipitation, percent slope, and the I-factor from the wind erosion equation*, as shown in the table below:

Soil wind erosion potential	Acres with I-factor <56	Acres with I-factor <134 and >=56	Acres with I-factor <250 and >=134	Acres with I-factor >=250
Low	Precipitation>=635 mm	Precipitation>=767 mm	Precipitation>=767 mm	None
Moderate	Precipitation<635 mm but >380mm	Precipitation<767 mm but >=508mm and slope>0.5	Precipitation <767 mm but >=635 mm or Precipitation <635 mm but >=508 mm and slope>=3	None
Moderately high	Precipitation<=380 mm	Precipitation<767 mm but >=508 mm and slope<=0.5 or Precipitation <508 mm	Precipitation <635 mm but >=508 mm and slope<3	None
High	None	None	Precipitation<508mm	All acres

* The I-factor from the wind erosion equation is a soil-erodibility index related to cloddiness.
Note: About 44 percent of the cropped acres in the basin are in the eastern portion and 56 percent are in the western portion.
Note: See appendix B, table B3, for a breakdown of soil wind erosion potential by subregion.

Figure 73. Soil wind erosion potential for soils in the Missouri River Basin



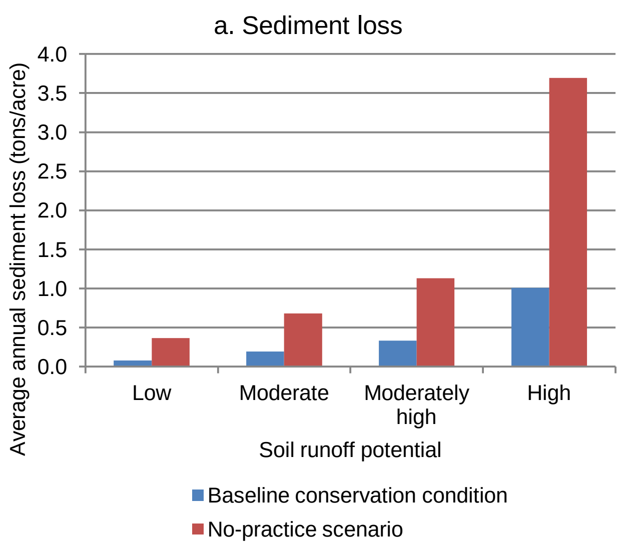
Note: The soil wind erosion potential shown in this map was derived using the criteria presented in figure 72 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

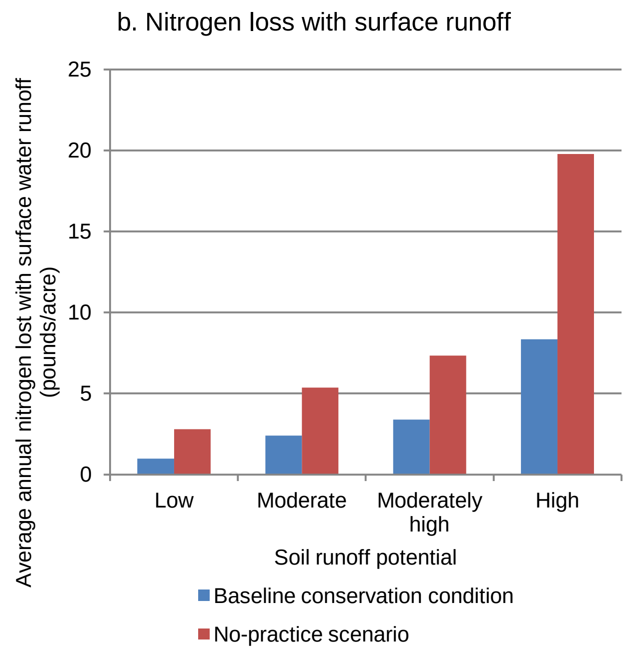
Estimates of sediment and nutrient losses for the no-practice scenario (without conservation practices), presented in figure 74, demonstrate how vulnerability factors influence losses in the Missouri River Basin. Estimates of sediment loss, nutrient loss, and wind erosion for the no-practice scenario consistently increased from small losses for the low vulnerability potentials to large losses for the high vulnerability potentials.

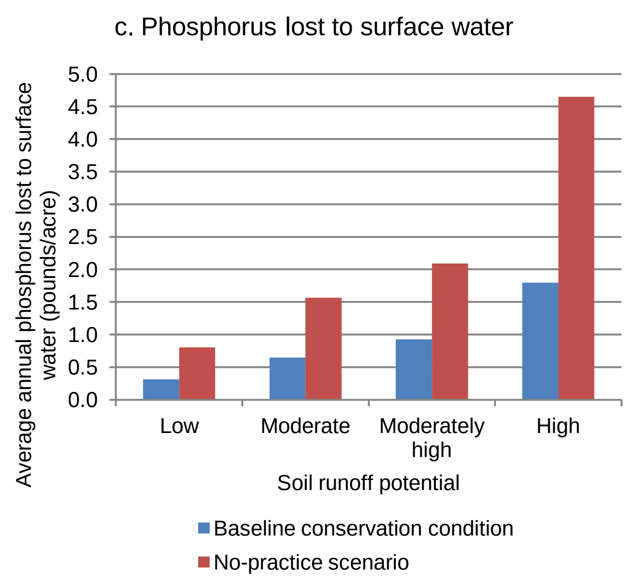
- Sediment loss for acres with a high soil runoff potential would have averaged nearly 4 tons per acre per year without conservation practices, compared to 0.4 ton per acre per year for acres with a low soil runoff potential (fig. 74a).
- Nitrogen loss with surface runoff for acres with a high soil runoff potential would have averaged 20 pounds per acre per year, compared to 2.8 pounds per acre per year for acres with a low soil runoff potential (fig. 74b).
- Phosphorus lost to surface water for acres with a high soil runoff potential would have averaged 4.6 pounds per acre per year, compared to 0.8 pound per acre per year for acres with a low soil runoff potential (fig. 74c).
- Nitrogen loss in subsurface flows for acres with a high soil leaching potential would have averaged 33 pounds per acre per year, compared to 9 pounds per acre per year for acres with a low soil leaching potential (fig. 74d).
- Wind erosion for acres with a high wind erosion potential would have averaged 8 tons per acre per year, compared to 0.7 ton per acre per year for acres with a low wind erosion potential (fig. 74e).

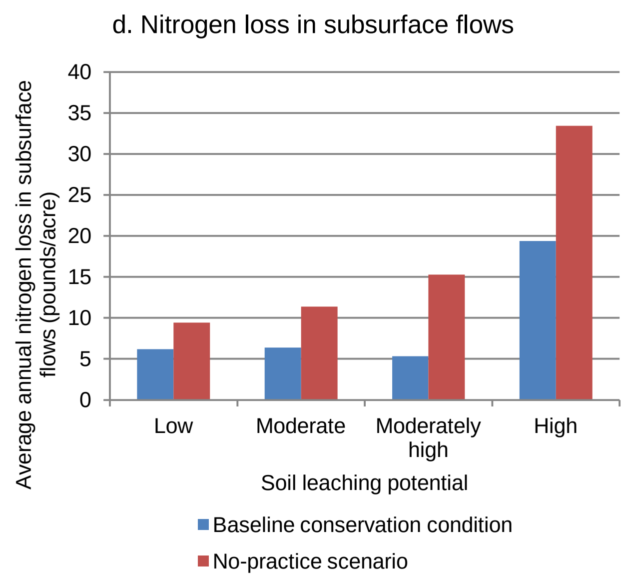
Estimates for the baseline are also presented in figure 74 to show how current levels of conservation treatment have reduced losses at each of the four vulnerability levels. Baseline estimates reflect the same general trend of increasing losses with increased vulnerability, but the trend is not always consistent (see fig. 74d) as the use of conservation practices is also a factor in the determination of erosion and nutrient losses.

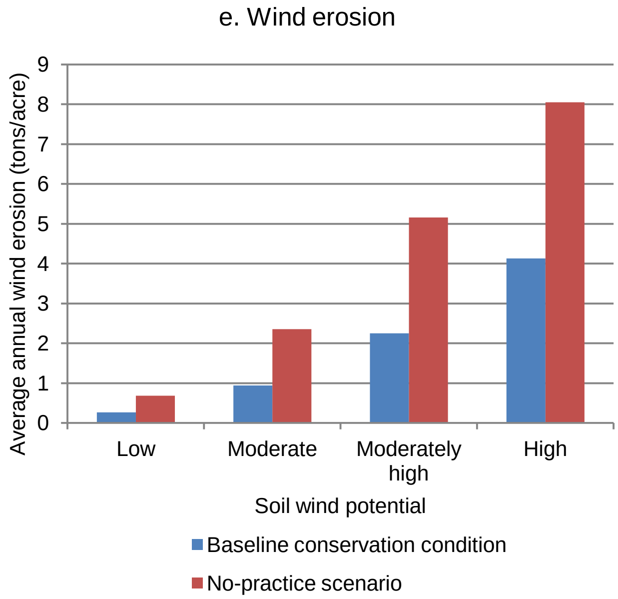
Figure 74. Average annual wind erosion, sediment loss, and nutrient losses for four levels of vulnerability potentials, Missouri River Basin











e. Wind erosion
Average annual wind erosion (tons/acre)
9
8
7
6
5
4
3
2
1
0
Low
Moderate
Moderately high
High
Soil wind potential
Baseline conservation condition
No-practice scenario

Evaluation of Conservation Treatment

The "matrix approach"

A "matrix approach" was used to identify acres where the level of conservation treatment is inadequate relative to the level of inherent vulnerability. These acres are referred to as "under-treated acres." Cropped acres were divided into 16 groups—defined by the four soil vulnerability potentials and four conservation treatment levels. The evaluation of conservation treatment needs was conducted by identifying which of the 16 groups of acres are inadequately treated with respect to the vulnerability potential.

The matrixes are presented for each of the five resource concerns in tables 26 through 30. Separate matrixes are used for the eastern and western portions of the basin to improve the capability of discriminating between high losses and lower losses. Each table includes seven sets of matrixes for each area that, taken together, capture the effects of conservation practices in the region and identifies the need for additional conservation treatment.

Acres and model results for each of the 16 groupings are presented in the first five matrixes in each table. The combination of the four soil vulnerability potentials and the four conservation treatment levels separates the acres with high losses from the acres with low losses. There generally is a trend of decreasing losses with increasing conservation treatment levels within each vulnerability potential. The tables also demonstrate that the high and moderately high treatment levels are effective in reducing losses for all vulnerability potentials.

The last two matrixes in each table show how conservation treatment needs were identified. Three levels of conservation treatment need were defined.

- **Acres with a "high" level of need** for conservation treatment consist of the most critical under-treated acres in the region. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest erosion and/or loss of nutrients.

- **Acres with a "moderate" level of need** for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability or have more conservation practice use than acres with a high level of need. The treatment level required is not necessarily less, although it can be, but rather the soil and nutrient losses are lower and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment.

- **Acres with a "low" level of need** for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. While gains can be attained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

Specific criteria were used to identify the groups of acres that fall into each of the three levels of conservation treatment need. Criteria were <u>not</u> tailored to a specific region, but were derived for use in all regions of the country to allow for comparisons of under-treated acres across regions using a consistent analytical framework.

The criteria and steps in the process are as follows—

1. The percentage of acres that exceeded a given level of loss was estimated for each cell in the matrix as a guide to determining the extent of excessive losses. These are referred to as "acceptable levels." *Losses above these levels were treated as unacceptable levels of loss.* "Acceptable levels"[31] for field-level losses used in this study are—
   - Average of 2 tons per acre per year for sediment loss,
   - Average of 15 pounds per acre per year for nitrogen loss with surface runoff (soluble and sediment attached),
   - Average of 25 pounds per acre per year for nitrogen loss in subsurface flows,
   - Average of 4 pounds per acre per year for phosphorus lost to surface water (soluble and sediment attached), and
   - Average wind erosion of 4 tons per acre per year.
2. Groups of acres with less than 30 percent of the acres exceeding acceptable levels were defined as adequately treated acres and designated as having a **low level of conservation treatment need**.
3. Groups of acres with more than 60 percent of the acres in excess of acceptable levels were designated as having a **high level of conservation treatment need,** indicated by darker shaded cells in the matrixes.
4. The remaining acres were designated as having a **moderate level of conservation treatment need**, indicated by lighter shaded cells in the matrix.

Under-treated acres—those groups of acres with either a high or moderate level of conservation treatment need—are shown in the last matrix in each table. In most cases, under-treated acres consist of acres where the conservation treatment level was one step or more below the soil vulnerability potential.

[31] The long-term average loss was used as the criteria because losses vary considerably from year to year, and the evaluation is intended to assess the adequacy of conservation treatment over all years, on average. Average annual losses derived from APEX model output simulated over 47 years of actual weather (1960 through 2006) were compared to the acceptable level criteria for each sample point.

Acceptable levels were initially derived through a series of forums held at professional meetings of researchers working on fate and transport of sediment and nutrients in agriculture. Those meetings produced a range of estimates for edge-of-field sediment loss, nitrogen loss, and phosphorus loss, representing what could be realistically achieved with today's production and conservation technologies. The range was narrowed by further examination of APEX model output, which also showed that the levels selected were agronomically feasible in all agricultural regions of the country. In the Missouri River Basin, for example, percentages of acres that can attain these acceptable levels with additional soil erosion control and nutrient management practices on all under-treated acres are (see the next chapter)—

- 99 percent of cropped acres for sediment loss,
- 99 percent of cropped acres for nitrogen loss with surface runoff,
- 98 percent of cropped acres for nitrogen loss in subsurface flows,
- 99 percent of cropped acres for phosphorus lost to surface water, and
- 98 percent of cropped acres for wind erosion.

The criteria used to identify acres that need additional conservation treatment, including acceptable levels, are not intended to provide adequate protection of water quality, although for some environmental settings they may be suitable for that purpose. Evaluation of how much conservation treatment is needed to meet Federal, State, and/or local water quality goals in the region is beyond the scope of this study.

Why Was a Threshold Approach Not Used?

A threshold approach is where all acres with edge-of-field losses above a specific level are identified as under-treated acres; and thus, all acres below that level of loss are considered adequately treated. A threshold approach is often used in regulatory schemes to denote compliance versus non-compliance.

A threshold approach is impractical for use in evaluating the adequacy of conservation practice use at the field level. Determination of the threshold level would need to be based on the environmental goals for a watershed, which would be expected to vary from watershed to watershed. Different thresholds would likely be needed for each field, depending on the cropping system. Moreover, sediment and nutrient losses vary from year to year; a specific set of practices shown to reduce losses below a specific level in some years will fail to do so in other years, even among acres that are fully treated. Inexpensive monitoring technologies do not exist for estimating sediment and nutrient losses on a field-by-field basis to determine what level of treatment is needed to meet an edge-of-field loss threshold, further hampering adaptive management efforts by producers.

The conservation goal is full treatment—not treatment to an arbitrary threshold. Protocols for full treatment—avoid, control, and trap—apply equally to all fields in all settings. The hallmark of the matrix approach is that the acres with treatment needs can be readily identified by farmers and conservation planners and treated as needed. Soil vulnerability levels and the existing conservation treatment levels can be readily determined during the conservation planning process.

Table 26. Identification of under-treated acres for sediment loss due to water erosion in the Missouri River Basin

Soil runoff potential	Low	Moderate	Moderately high	High	All	Low	Moderate	Moderately high	High	All
	Conservation treatment levels for water erosion control									
	Eastern portion of basin					**Western portion of basin**				
Estimated cropped acres										
Low	437,467	3,636,820	1,832,816	10,879,021	16,786,125	2,383,822	15,799,499	2,684,913	6,888,967	27,757,201
Moderate	529,511	1,571,860	1,182,038	2,455,947	5,739,357	1,566,885	1,993,589	329,082	359,989	4,249,544
Moderately high	391,146	2,432,435	3,014,790	1,415,144	7,253,516	3,437,096	6,614,844	1,114,792	606,063	11,772,795
High	370,847	2,094,132	3,911,876	202,148	6,579,003	1,114,878	1,938,902	423,180	0	3,476,960
All	1,728,972	9,735,247	9,941,520	14,952,260	36,358,000	8,502,681	26,346,834	4,551,966	7,855,019	47,256,500
Percent of cropped acres										
Low	1	10	5	30	46	5	33	6	15	59
Moderate	1	4	3	7	16	3	4	1	1	9
Moderately high	1	7	8	4	20	7	14	2	1	25
High	1	6	11	1	18	2	4	1	0	7
All	5	27	27	41	100	18	56	10	17	100
Sediment loss estimates *without* conservation practices (no-practice scenario), average annual tons/acre										
Low	0.23	0.47	0.84	0.43	0.47	0.46	0.20	0.16	0.53	0.30
Moderate	0.52	0.76	1.61	0.95	1.00	0.40	0.13	0.20	0.38	0.26
Moderately high	4.24	2.48	2.58	1.52	2.43	0.26	0.28	0.94	0.25	0.34
High	9.59	5.37	4.32	5.02	4.97	0.57	1.67	1.36	NA	1.28
All	3.23	2.07	2.83	0.68	1.76	0.38	0.32	0.47	0.50	0.38
Sediment loss estimates for the baseline conservation condition, average annual tons/acre										
Low	0.17	0.20	0.22	0.10	0.14	0.06	0.04	0.02	0.06	0.04
Moderate	0.33	0.33	0.29	0.26	0.29	0.10	0.05	0.05	0.04	0.07
Moderately high	2.23	0.91	0.48	0.33	0.69	0.13	0.11	0.10	0.06	0.11
High	5.10	1.95	0.81	0.05	1.39	0.36	0.26	0.15	NA	0.28
All	1.74	0.77	0.54	0.15	0.50	0.13	0.07	0.06	0.06	0.08
Percent reduction in sediment loss due to conservation practices, average annual tons/acre										
Low	23	58	73	76	71	86	81	85	88	85
Moderate	37	57	82	73	71	75	63	74	89	74
Moderately high	47	63	81	78	72	50	60	89	77	66
High	47	64	81	99	72	36	84	89	NA	78
All	46	63	81	78	72	65	77	88	88	79
Percent of acres in baseline with average annual sediment loss more than 2 tons/acre										
Low	0	1	1	0	0	0	0	0	0	0
Moderate	3	0	0	0	0	0	0	0	0	0
Moderately high	40	16	2	0	9	0	0	0	0	0
High	84	37	5	0	20	2	1	0	NA	1
All	28	12	3	0	5	1	0	0	0	0
Estimate of under-treated acres for sediment loss										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	0	0	0	0	0	0	0	0	0	0
Moderately high	391,146	0	0	0	391,146	0	0	0	0	0
High	370,847	2,094,132	0	0	2,464,979	0	0	0	0	0
All	761,994	2,094,132	0	0	2,856,125	0	0	0	0	0

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.
Note: NA indicates not applicable because there were no acres in the category.

Table 27. Identification of under-treated acres for nitrogen loss with surface runoff (sediment attached and soluble) in the Missouri River Basin

	Conservation treatment levels for nitrogen runoff control									
	Low	Moderate	Moderately high	High	All	Low	Moderate	Moderately high	High	All
Soil runoff potential	**Eastern portion of basin**					**Western portion of basin**				
Estimated cropped acres										
Low	199,705	4,863,913	10,162,039	1,560,468	16,786,125	1,029,403	12,780,189	12,842,951	1,104,658	27,757,201
Moderate	152,200	1,979,236	3,181,660	426,261	5,739,357	312,810	2,583,052	1,215,476	138,206	4,249,544
Moderately high	208,072	3,117,332	3,656,076	272,036	7,253,516	838,407	7,552,108	3,120,684	261,597	11,772,795
High	187,488	2,879,465	3,453,606	58,444	6,579,003	506,659	2,641,479	328,821	0	3,476,960
All	747,466	12,839,945	20,453,381	2,317,209	36,358,000	2,687,278	25,556,828	17,507,932	1,504,461	47,256,500
Percent of cropped acres										
Low	1	13	28	4	46	2	27	27	2	59
Moderate	<1	5	9	1	16	1	5	3	0	9
Moderately high	1	9	10	1	20	2	16	7	1	25
High	1	8	9	<1	18	1	6	1	0	7
All	2	35	56	6	100	6	54	37	3	100
Estimates of nitrogen loss with surface water runoff *without* conservation practices (no-practice scenario), average annual pounds/acre										
Low	3	4	4	2	4	3	2	2	2	2
Moderate	4	7	9	7	8	7	1	2	0	2
Moderately high	35	14	15	7	15	3	3	2	1	3
High	49	29	24	22	27	9	6	2	NA	6
All	24	13	10	4	11	5	3	2	2	2
Estimates of nitrogen loss with surface water runoff for the baseline conservation condition, average annual pounds/acre										
Low	2	2	2	1	2	1	1	1	1	1
Moderate	2	3	4	3	4	2	1	1	0	1
Moderately high	24	8	6	3	7	2	1	1	1	1
High	32	15	8	1	12	3	2	1	NA	2
All	16	6	4	2	5	2	1	1	1	1
Percent reduction in nitrogen loss with surface water runoff due to conservation practices, average annual pounds/acre										
Low	39	54	60	52	58	77	75	75	60	74
Moderate	37	50	57	53	55	76	42	60	30	58
Moderately high	30	47	63	57	54	47	53	58	59	54
High	34	49	67	95	57	70	62	50	NA	63
All	33	49	63	59	56	67	63	70	59	66
Percent of acres in baseline with average annual nitrogen loss with surface runoff more than 15 pounds/acre										
Low	0	1	0	0	0	0	0	0	0	0
Moderate	0	1	0	0	0	0	0	0	0	0
Moderately high	66	20	5	0	13	2	0	0	0	0
High	76	40	12	0	26	5	1	0	NA	1
All	38	14	3	0	7	2	0	0	0	0
Estimate of under-treated acres for nitrogen loss with surface runoff										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	0	0	0	0	0	0	0	0	0	0
Moderately high	208,072	0	0	0	208,072	0	0	0	0	0
High	187,488	2,879,465	0	0	3,066,953	0	0	0	0	0
All	395,560	2,879,465	0	0	3,275,025	0	0	0	0	0

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.
Note: NA indicates not applicable because there were no acres in the category.

Table 28. Identification of under-treated acres for nitrogen loss in subsurface flows in the Missouri River Basin

Soil runoff potential	Low	Moderate	Moderately high	High	All	Low	Moderate	Moderately high	High	All
	Conservation treatment levels for nitrogen runoff control									
	Eastern portion of basin					Western portion of basin				
Estimated cropped acres										
Low	314,728	1,674,719	2,730,245	1,175,864	5,895,557	176,944	773,092	1,009,275	977,853	2,937,164
Moderate	2,871,369	8,655,442	12,903,261	4,835,513	29,265,585	1,795,313	10,321,444	9,889,872	14,303,788	36,310,417
Moderately high	10,959	23,207	213,957	64,621	312,745	137,258	728,953	1,180,959	2,720,592	4,767,763
High	125,165	298,955	299,502	160,491	884,113	284,776	1,129,516	861,527	965,337	3,241,156
All	3,322,222	10,652,323	16,146,965	6,236,490	36,358,000	2,394,291	12,953,005	12,941,634	18,967,571	47,256,500
Percent of cropped acres										
Low	1	5	8	3	16	<1	2	2	2	6
Moderate	8	24	35	13	80	4	22	21	30	77
Moderately high	<1	<1	1	<1	1	<1	2	2	6	10
High	<1	1	1	<1	2	1	2	2	2	7
All	9	29	44	17	100	5	27	27	40	100
Estimates of nitrogen loss in subsurface flows *without* conservation practices (no-practice scenario), average annual pounds/acre										
Low	5	5	13	6	9	26	9	11	9	11
Moderate	17	13	10	9	11	17	11	12	11	12
Moderately high	38	25	21	8	19	27	24	16	11	15
High	28	43	23	14	29	70	40	32	21	35
All	17	13	11	9	11	25	14	13	11	13
Estimates of nitrogen loss in subsurface flows for the baseline conservation condition, average annual pounds/acre										
Low	6	6	8	4	7	17	6	4	3	5
Moderate	15	14	6	5	9	9	6	4	3	4
Moderately high	34	22	4	6	7	21	14	3	3	5
High	20	39	12	6	21	44	29	13	5	19
All	14	13	7	5	9	14	9	4	3	5
Percent reduction in nitrogen loss in subsurface flows due to conservation practices, average annual pounds/acre										
Low	-23	-19	35	23	23	36	32	62	67	53
Moderate	14	-6	35	44	19	49	46	69	76	63
Moderately high	10	13	82	30	66	25	41	79	75	65
High	30	10	45	55	26	37	28	60	74	46
All	13	-5	37	42	21	42	40	68	75	60
Percent of acres in baseline with average annual nitrogen loss in subsurface flows more than 25 pounds/acre										
Low	2	2	3	1	2	21	1	0	1	2
Moderate	14	14	1	0	6	7	5	1	0	2
Moderately high	NA	0	0	0	4	27	24	1	0	5
High	22*	38	10	0	19	60	40	13	2	23
All	13	13	2	0	6	16	9	2	0	4
Estimate of under-treated acres for nitrogen loss in subsurface flows										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	0	0	0	0	0	0	0	0	0	0
Moderately high	0	0	0	0	0	0	0	0	0	0
High	125,165	298,955	0	0	424,120	284,776	1,129,516	0	0	1,414,292
All	125,165	298,955	0	0	424,120	284,776	1,129,516	0	0	1,414,292

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

Note: NA indicates not applicable because there were too few acres in the category.

* This group of acres was classified as under-treated acres because a higher level of conservation treatment met the criteria for under-treated acres. Sample size was very small for this cell.

Table 29. Identification of under-treated acres for phosphorus lost to surface water (attached to sediment and in solution) in the Missouri River Basin

	Conservation treatment levels for nitrogen runoff control									
	Low	Moderate	Moderately high	High	All	Low	Moderate	Moderately high	High	All
Soil runoff potential	**Eastern portion of basin**					**Western portion of basin**				
Estimated cropped acres										
Low	502,796	4,589,705	6,155,260	5,538,364	16,786,125	2,303,930	10,277,696	11,656,641	3,518,934	27,757,201
Moderate	286,702	1,872,231	2,342,112	1,238,311	5,739,357	438,437	2,381,087	1,303,302	126,718	4,249,544
Moderately high	380,734	2,696,661	3,455,359	720,762	7,253,516	2,008,252	6,436,614	3,027,777	300,152	11,772,795
High	346,801	2,777,915	3,362,670	91,616	6,579,003	715,878	2,279,126	481,956	0	3,476,960
All	1,517,034	11,936,512	15,315,402	7,589,053	36,358,000	5,466,497	21,374,524	16,469,675	3,945,805	47,256,500
Percent of cropped acres										
Low	1	13	17	15	46	5	22	25	7	59
Moderate	1	5	6	3	16	1	5	3	<1	9
Moderately high	1	7	10	2	20	4	14	6	1	25
High	1	8	9	<1	18	2	5	1	0	7
All	4	33	42	21	100	12	45	35	8	100
Estimates of phosphorus lost to surface water *without* conservation practices (no-practice scenario), average annual pounds/acre										
Low	1.38	1.02	1.26	1.38	1.24	0.51	0.43	0.49	1.07	0.54
Moderate	1.77	1.77	2.67	3.03	2.41	0.33	0.44	0.39	0.89	0.42
Moderately high	5.54	5.13	4.07	3.20	4.46	0.33	0.72	0.63	1.04	0.64
High	7.97	6.67	6.17	6.69	6.48	1.85	0.86	1.69	NA	1.18
All	4.01	3.38	3.19	1.89	3.01	0.60	0.56	0.55	1.06	0.60
Estimates of phosphorus lost to surface water for the baseline conservation condition, average annual pounds/acre										
Low	1.08	0.75	0.49	0.45	0.56	0.31	0.16	0.11	0.23	0.16
Moderate	1.12	1.12	0.93	0.87	0.99	0.21	0.16	0.19	0.43	0.18
Moderately high	4.30	2.74	1.21	0.92	1.91	0.31	0.31	0.32	0.43	0.32
High	5.60	3.13	1.74	0.42	2.51	0.44	0.47	0.26	NA	0.44
All	2.93	1.81	0.99	0.56	1.25	0.32	0.24	0.16	0.25	0.22
Percent reduction in phosphorus lost to surface water due to conservation practices, average annual pounds/acre										
Low	22	26	61	67	54	40	62	78	78	71
Moderate	37	37	65	71	59	38	63	51	52	57
Moderately high	22	47	70	71	57	4	57	49	59	50
High	30	53	72	94	61	76	45	85	NA	63
All	27	46	69	70	58	47	57	71	76	63
Percent of acres in baseline with average annual phosphorus lost to surface water more than 4 pounds/acre										
Low	6	2	0	1	1	1	0	0	0	0
Moderate	4	5	0	0	2	0	0	0	0	0
Moderately high	37	22	2	0	11	1	1	0	0	0
High	62	29	6	0	19	0	2	0	NA	1
All	26	14	2	1	6	1	0	0	0	0
Estimate of under-treated acres for phosphorus lost to surface water										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	0	0	0	0	0	0	0	0	0	0
Moderately high	380,734	0	0	0	380,734	0	0	0	0	0
High	346,801	0	0	0	346,801	0	0	0	0	0
All	727,535	0	0	0	727,535	0	0	0	0	0

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.
Note: NA indicates not applicable because there were no acres in the category.

Table 30. Identification of under-treated acres for wind erosion due to water erosion in the Missouri River Basin

	Conservation treatment levels for water erosion control									
	Low	Moderate	Moderately high	High	All	Low	Moderate	Moderately high	High	All
Soil runoff potential	**Eastern portion of basin**					**Western portion of basin**				
Estimated cropped acres										
Low	784,413	9,818,098	11,110,255	670,172	22,382,938	961,889	1,081,006	1,042,472	87,241	3,172,609
Moderate	339,431	5,145,836	4,850,895	1,292,787	11,628,948	1,742,026	10,055,604	9,600,851	1,970,517	23,368,998
Moderately high	233,799	1,170,587	529,342	327,821	2,261,550	1,281,938	7,763,060	8,279,329	2,182,296	19,506,623
High	0	19,948	21,585	43,032	84,565	33,961	716,633	303,793	153,883	1,208,270
All	1,357,643	16,154,469	16,512,076	2,333,812	36,358,000	4,019,815	19,616,303	19,226,445	4,393,937	47,256,500
Percent of cropped acres										
Low	2	27	31	2	62	2	2	2	0	7
Moderate	1	14	13	4	32	4	21	20	4	49
Moderately high	1	3	1	1	6	3	16	18	5	41
High	0	<1	<1	<1	0	<1	2	1	<1	3
All	4	44	45	6	100	9	42	41	9	100
Wind erosion estimates *without* conservation practices (no-practice scenario), average annual tons/acre										
Low	0.96	0.80	0.50	0.57	0.65	0.89	1.21	0.69	0.60	0.93
Moderate	4.12	2.21	2.00	2.05	2.16	2.66	2.67	2.07	3.00	2.45
Moderately high	4.00	3.79	2.93	5.41	3.84	6.71	6.21	4.39	4.73	5.31
High	NA	NA	NA	NA	5.05	30.85	9.36	5.65	3.35	8.26
All	2.27	1.47	1.01	2.19	1.34	3.77	4.24	3.05	3.83	3.68
Wind erosion estimates for the baseline conservation condition, average annual tons/acre										
Low	0.85	0.34	0.09	0.08	0.23	0.91	0.67	0.17	0.06	0.56
Moderate	3.37	0.94	0.45	0.27	0.73	2.51	1.52	0.43	0.37	1.05
Moderately high	3.48	1.47	0.57	0.49	1.33	5.43	3.69	1.09	0.59	2.36
High	NA	NA	NA	NA	1.71	30.61	4.92	1.97	0.21	4.30
All	1.93	0.62	0.21	0.27	0.46	3.29	2.46	0.73	0.47	1.64
Percent reduction in wind erosion due to conservation practices, average annual tons/acre										
Low	11	57	83	87	65	-3	45	75	91	39
Moderate	18	58	78	87	66	6	43	79	88	57
Moderately high	13	61	81	91	65	19	41	75	87	56
High	NA	NA	NA	NA	66	1	47	65	94	48
All	15	58	80	88	66	13	42	76	88	55
Percent of acres in baseline with average annual wind erosion more than 4 tons/acre										
Low	0	0	0	0	0	4	0	0	0	1
Moderate	29	2	0	0	2	14	6	1	0	4
Moderately high	41	5	0	0	7	43	35	6	2	19
High	NA	NA	NA	NA	0	79	37	30	0	32
All	14	1	0	0	1	21	18	3	1	11
Estimate of under-treated acres for wind erosion										
Low	0	0	0	0	0	0	0	0	0	0
Moderate	0	0	0	0	0	0	0	0	0	0
Moderately high	233,799	0	0	0	233,799	1,281,938	7,763,060	0	0	9,044,998
High	0	0	0	0	0	33,961	716,633	303,793	0	1,054,387
All	233,799	0	0	0	233,799	1,315,899	8,479,693	303,793	0	10,099,385

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.
Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.

Conservation treatment needs by resource concern

Most of the cropped acres in the Missouri River Basin were determined to have a low need for additional conservation treatment for all five resource concerns. The percentage of cropped acres in the Missouri River basin with a high or moderate need for additional conservation treatment was determined to be (fig. 75 and table 31)—

- 3.4 percent for sediment loss (0.4 percent with a high need for treatment),
- 3.9 percent for nitrogen loss with surface runoff (0.5 percent with a high need for treatment),
- 0.9 percent for phosphorus lost to surface water (0.4 percent with a high need for treatment),
- 2.2 percent for nitrogen loss in subsurface flows (0.3 percent with a high need for treatment), most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow, and
- 12.4 percent for wind erosion (less than 0.1 percent with a high need for treatment).

Most of the under-treated acres for wind erosion and nitrogen loss in subsurface flows are in the western portion of the basin. Most of the under-treated acres for resource concerns associated with water runoff are in the eastern portion of the basin (table 31).

Under-treated acres in the Missouri River Basin are presented by combinations of resource concerns in table 32. Nearly 80 percent of the under-treated acres are under-treated for only one of the five resource concerns:

- 62 percent of under-treated acres are under-treated only for wind erosion,
- 7 percent of under-treated acres are under-treated only for nitrogen leaching,
- 6 percent of under-treated acres are under-treated only for nitrogen runoff, and
- about 3 percent of under-treated acres are under-treated for sediment loss only.

Figure 75. Percent of cropped acres that are under-treated in the Missouri River Basin, by resource concern

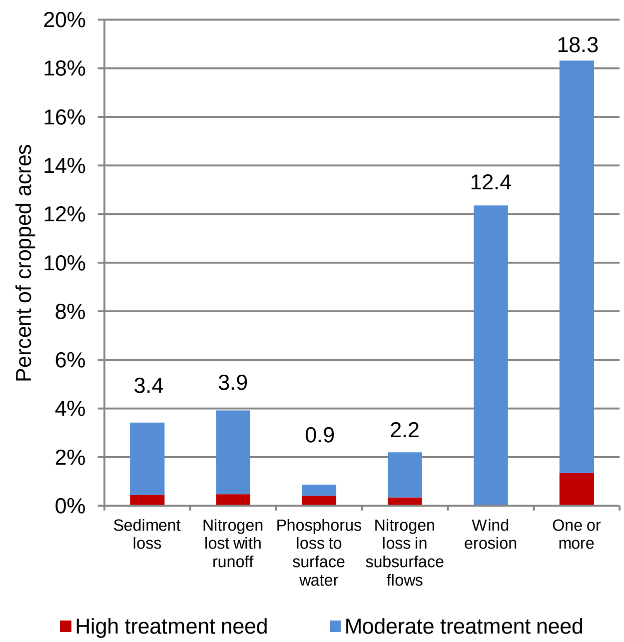


Table 31. Percent of cropped acres in the Missouri River basin with conservation treatment needs for each of the five resource concerns

	Sediment loss	Nitrogen loss with surface runoff	Phosphorus lost to surface water	Nitrogen loss in subsurface flows	Wind erosion	One or more
High level of conservation treatment need						
Eastern portion of basin	0.4	0.5	0.4	0.0	0.0	1.0
Western portion of basin	0.0	0.0	0.0	0.3	<0.1	0.4
Total for basin	0.4	0.5	0.4	0.3	<0.1	1.3
Moderate level of conservation treatment need						
Eastern portion of basin	3.0	3.4	0.5	0.5	0.3	4.4
Western portion of basin	0.0	0.0	0.0	1.4	12.0	12.5
Total for basin	3.0	3.4	0.5	1.9	12.3	17.0
Low level of conservation treatment need						
Eastern portion of basin	40.1	39.6	42.6	43.0	43.2	38.0
Western portion of basin	56.5	56.5	56.5	54.8	44.4	43.6
Total for basin	96.6	96.1	99.1	97.8	87.6	81.7

Table 32. Under-treated acres with resource concerns needing treatment in the Missouri River Basin

	Eastern portion		Western portion		Total for basin	
Reason for treatment need	Percent of cropped acres in basin	Percent of under-treated acres in basin	Percent of cropped acres in basin	Percent of under-treated acres in basin	Percent of cropped acres in basin	Percent of under-treated acres in basin
Wind erosion only	0.2	1.1	11.2	61.1	11.4	62.1
Phosphorus runoff only	0.2	0.9	0.0	0.0	0.2	0.9
Nitrogen leaching only	0.5	2.8	0.8	4.3	1.3	7.1
Nitrogen leaching and wind erosion	0.0	0.0	0.9	4.9	0.9	4.9
Nitrogen runoff only	1.1	6.0	0.0	0.0	1.1	6.0
Phosphorus runoff and nitrogen runoff	0.1	0.3	0.0	0.0	0.1	0.3
Sediment loss only	0.5	2.7	0.0	0.0	0.5	2.7
Sediment loss and phosphorus runoff	0.1	0.4	0.0	0.0	0.1	0.4
Sediment loss, wind erosion, and phosphorus runoff	0.1	0.5	0.0	0.0	0.1	0.5
Sediment loss and nitrogen runoff	2.3	12.4	0.0	0.0	2.3	12.4
Sediment loss, nitrogen runoff. phosphorus runoff	0.5	2.7	0.0	0.0	0.5	2.7
All under-treated acres	5.4	29.7	12.9	70.3	18.3	100.0

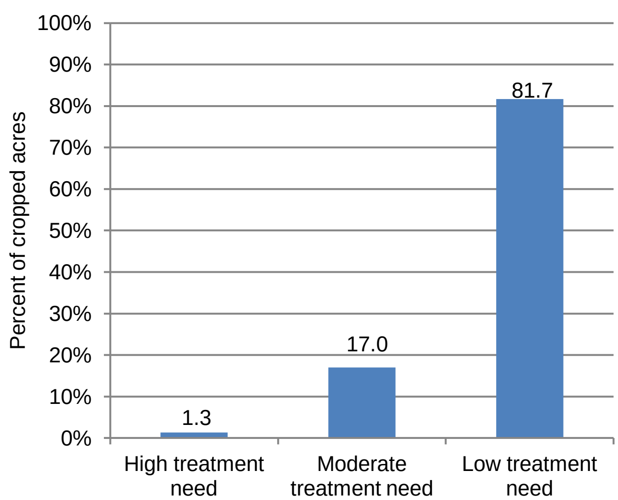
Note: This table summarizes the under-treated acres identified in tables 26-30 and reports the joint set of acres that need treatment according to combinations of resource concerns.
Note: Percents may not add to totals because of rounding.

Conservation treatment needs for one or more resource concern

Some acres require additional treatment for only one of the five resource concerns, while other acres require additional treatment for two or more resource concerns. After accounting for acres that need treatment for multiple resource concerns, the evaluation of treatment needs for the Missouri River Basin determined the following (fig. 76):

- 1 percent of cropped acres (1.1 million acres) have a **high** level of need for additional conservation treatment,
- 17 percent of cropped acres (14.2 million acres) have a **moderate** level of need for additional conservation treatment, and
- 82 percent of cropped acres (68.3 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.

Figure 76. Percent of cropped acres with a high, moderate, or low level of need for additional conservation treatment for one or more resource concern in the Missouri River Basin



High level of need for conservation treatment. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients. In the Missouri River Basin, these 1.1 million acres lose (per acre per year, on average) 3.1 tons of sediment by water erosion, 8.0 pounds of phosphorus, and 58 pounds of nitrogen. Wind erosion averages 2.0 tons per acre per year (table 33).

Moderate level of need for conservation treatment. Acres with a "moderate" level of need for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability and or have more conservation practice use than do acres with a high level of need. In the Missouri River Basin, these 14.2 million acres lose (per acre per year, on average) 0.4 ton of sediment by water erosion, 2.6 pounds of phosphorus, and 30 pounds of nitrogen. Wind erosion averages 2.9 tons per acre per year (table 33).

Low level of need for conservation treatment. Acres with a low level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. In the Missouri River Basin, these 68.3million acres lose (per acre per year, on average) 0.2 ton of sediment by water erosion, 1.4 pounds of phosphorus, and 21 pounds of nitrogen. Wind erosion averages 0.7 tons per acre per year (table 33).

While gains can be attained by adding conservation practices to some of these acres with a low treatment need, additional conservation treatment would reduce field losses by only a small amount.

What is “Adequate Conservation Treatment?”

This study found that about 82 percent of the cropped acres in the Missouri River Basin had a “low” level of conservation treatment need and were considered to be “adequately treated.” This is in part due to the relatively lower vulnerability potential for most cropped acres in this region as compared to other regions. As shown in the next chapter, additional conservation treatment for these acres with a “low” need for treatment is expected to provide small per-acre reductions in erosion and nutrient losses, requiring a large number of acres to be treated in order to have a significant impact at the subregional and regional levels.

Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment, nutrient, and pesticide losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to soluble nutrient and pesticide losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

In practice, a *comprehensive planning process* is used to identify the appropriate combination of nutrient management techniques, soil erosion control practices, and other conservation practices needed to address the specific inherent vulnerabilities associated with each field. A field with adequate conservation practice use will have combinations of practices that address all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses. Full treatment consists of a suite of practices that—

- avoid or limit the potential for contaminant losses by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- control overland flow where needed; and
- trap materials leaving the field using appropriate edge-of-field mitigation.

In this report, adequate conservation treatment is limited to the use of practices that will not require changes in the cropping systems or changes in regional crop production levels.

In spite of the small per-acre potential gains, however, it may be necessary in some environmental settings to go beyond “adequate conservation treatment” to achieve local environmental goals.

Table 33. Baseline conservation condition model simulation results for subsets of under-treated and adequately treated acres in the Missouri River Basin

Model simulated outcome	Acres with a *low* need for treatment	Acres with a *moderate* need for treatment	Acres with a *high* need for treatment	All acres
Cultivated cropland acres in subset	68,308,429	14,179,371	1,126,701	83,614,500
Percent of acres	81.7%	17.0%	1.3%	100.0%
Water flow				
Average annual surface runoff (inches)	1.4	1.0	3.0	1.3
Average annual subsurface water flow (inches)	3.1	2.9	6.2	3.1
Erosion and sediment loss				
Average annual wind erosion (tons/acre)	0.74	2.91	1.97	1.13
Average annual sheet and rill erosion (tons/acre)	0.26	0.37	2.64	0.31
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.20	0.35	3.10	0.26
Soil organic carbon				
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	74	-42	-59	52
Nitrogen				
Nitrogen sources (pounds/acre)				
Atmospheric deposition	33	20	47	31
Bio-fixation by legumes	5	4	6	5
Nitrogen applied as commercial fertilizer and manure	64	68	100	65
All nitrogen sources	103	92	154	102
Nitrogen in crop yield removed at harvest (pounds/acre)	78	68	103	76
Total nitrogen loss for all pathways (pounds/acre)	21.4	30.2	58.1	23.4
Average annual loss of nitrogen through volatilization (pounds/acre)	6.5	5.4	7.6	6.3
Average annual nitrogen returned to the atmosphere through denitrification (pounds/acre)	1.7	2.2	2.9	1.8
Average annual nitrogen lost with windborne sediment (pounds/acre)	4.8	10.3	6.9	5.8
Average annual loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	2.2	3.0	19.3	2.6
Average annual nitrogen loss in subsurface flows (pounds/acre)	6.2	9.3	21.4	6.9
Phosphorus				
Phosphorus applied (pounds/acre)	14.2	13.2	27.2	14.2
Phosphorus in crop yield removed at harvest (pounds/acre)	12.1	10.6	15.9	11.9
Total phosphorus loss for all pathways (pounds/acre)	1.4	2.6	8.0	1.7
Average annual phosphorus lost with windborne sediment (pounds/acre)	0.8	1.9	3.1	1.0
Loss of phosphorus to surface water, including both soluble and sediment attached (pounds/acre)*	0.6	0.7	4.8	0.7
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	3.3	3.0	13.3	3.4
Average annual surface water pesticide risk indicator for aquatic ecosystem	1.3	1.3	2.6	1.3
Average annual surface water pesticide risk indicator for humans	0.3	0.2	0.6	0.3

* Includes phosphorus lost with waterborne sediment and soluble phosphorus in subsurface flows that are intercepted by tile drains and drainage ditches, lateral subsurface outflow (seeps), and groundwater return flow.

Conservation treatment needs by cropping systems

All cropping systems in this region have at least some under-treated acres, but six cropping systems have a disproportionately high percentage of acres that need additional treatment, shown in table 34. The most striking are wheat only and corn only. These two cropping systems make up 29 percent of the acres in the basin but 45 percent of the under-treated acres.

The proportions of acres that are under-treated for the remaining eight cropping systems are lower than their proportion of acres in the region. The most striking is the corn-soybean rotation. Corn-soybean rotations make up 32 percent of the cropped acres in the region, but only 20 percent of the under-treated acres in the region (table 34).

Table 34. Percent of under-treated acres (acres with a *high* or *moderate* level of treatment need) by cropping system, Missouri River Basin

Cropping system	Percent of cropped acres in Missouri River Basin	Percent of under-treated acres in Missouri River Basin	Percent of under-treated acres in cropping system
Disproportionately high percentage of under-treated acres			
Corn only	5.9	10.2	31.8
Wheat only	23.4	34.5	27.1
Hay-crop mix	5.5	8.0	26.8
Remaining close-grown crop systems	2.0	2.6	23.4
Remaining mix of row and close-grown crops	7.6	8.7	21.1
Vegetables with and without other crops	2.4	2.6	20.2
Disproportionately low percentage of under-treated acres			
Corn-soybean only	32.4	20.2	11.4
Sorghum with and without other crops	3.8	1.5	7.5
Sunflower and close-grown crops	2.4	1.0	7.6
Soybean-wheat only	3.2	1.4	8.2
Remaining row crops	1.7	1.3	13.8
Corn-soybean with close-grown crops	2.9	2.2	13.9
Soybeans only	1.8	1.4	14.2
Corn and close-grown crops	5.2	4.3	15.4
Total	100.0	100.0	18.3*

Note: Percents may not add to totals because of rounding.
* Percent of under-treated acres in the Missouri River Basin.

Conservation treatment needs by subregions

Under-treated acres in the Missouri River Basin are distributed throughout all of the subregions, but are the most concentrated in five subregions—the North Platte River Basin (code 1018), the Big Horn and Powder-Tongue River Basins (codes 1008, 1009), the Lower Yellowstone River (code 1010), and the South Platte River Basin (code 1019) (table 35). These five subregions include 7 percent of the cropped acres in the region but have 23 percent of the under-treated acres in the region. Ten other subregions have less pronounced disproportionately high percentages of under-treated acres, shown in table 35. These 10 regions include 33 percent of the cropped acres in the region and have 47 percent of the under-treated acres.

In contrast, 14 subregions have disproportionately low percentages of under-treated acres relative to cropped acres (table 35). These 14 subregions include 60 percent of the cropped acres in the region but have only 30 percent of the under-treated acres in the region.

See appendix B, table B5, for a subregion breakdown of conservation treatment needs by resource concern.

Table 35. Percent of under-treated acres (acres with a *high* or *moderate* level of treatment need) by subregion, Missouri River Basin

Subregion	Percent of cropped acres in Missouri River Basin	Percent of under-treated acres in Missouri River Basin	Percent of under-treated acres in subregion
Disproportionately high percentage of under-treated acres			
North Platte River Basin (code 1018)	1.2	4.8	75.0
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	0.7	2.5	61.6
Lower Yellowstone River (code 1010)	1.0	3.3	57.5
South Platte River Basin (code 1019)	4.0	12.3	57.2
Milk River Basin (code 1005)	2.4	5.0	38.1
Missouri-Musselshell-Fort Peck Lake (code 1004)	1.5	3.0	36.9
Missouri-Poplar River Basin (code 1006)	3.1	5.8	34.0
Niobrara River Basin (code 1015)	1.4	2.6	34.0
Elkhorn River Basin (code 1022)	2.8	3.9	25.6
Republican River Basin (code 1025)	9.4	13.1	25.4
Chariton-Grand River Basin (code 1028)	2.5	3.0	22.5
Upper Yellowstone River Basin (code 1007)	0.5	0.6	20.8
Missouri-Nishnabotna River Basin (code 1024)	6.2	6.7	19.7
Middle and Lower Platte River Basin (code 1020)	3.0	3.1	19.0
Disproportionately low percentage of under-treated acres			
Missouri-White River -Fort Randall Reservoir (code 1014)	3.2	0.1	0.8
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	6.8	1.9	5.2
Smoky Hill River Basin (code 1026)	8.5	2.5	5.3
Kansas-Big Blue River Basin (code 1027)	5.8	2.3	7.2
Gasconade-Osage River Basin (code 1029)	1.8	0.9	8.7
James River Basin (code 1016)	8.5	4.3	9.2
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	4.4	2.7	11.0
Loup River Basin (code 1021)	1.8	1.1	11.2
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	8.5	5.4	11.7
Missouri-Little Sioux River Basin (code 1023)	5.4	4.2	14.2
Lower Missouri-Lower Missouri-Blackwater (code 1030)	2.2	1.9	16.0
Missouri-Little Missouri-Lake Sakakawea (code 1011)	3.2	2.9	16.5
Total	100.0	100.0	18.3*

Note: Percents may not add to totals because of rounding.
* Percent of under-treated acres in the Missouri River Basin.

Chapter 6
Assessment of Potential Field-Level Gains from Further Conservation Treatment

Model simulations were used to evaluate the potential gains from further conservation treatment in the Missouri River Basin. The simulated treatment levels were designed to minimally affect crop yields and maintain regional production capacity for food, feed, fiber, and fuel. The existing practices were augmented with additional practices to—

- avoid or limit the potential for loss by using nutrient management practices (appropriate rate, timing, form *and* method) on *all* crops in the rotation;
- control overland flow where needed; and
- trap materials leaving the field using appropriate edge-of-field mitigation where absent.

Three sets of additional conservation practices were simulated:

1. Additional wind and water erosion control practices consisting of four types of structural practices—overland flow practices, concentrated flow practices, edge-of-field mitigation—and wind erosion control practices.
2. Application of nitrogen and phosphorus using appropriate rate, timing, and method.
3. Increases in the efficiency of irrigation water application.

Four conservation treatment scenarios were simulated to evaluate the potential gains from further conservation treatment:

1. Treatment of the 1.1 million critical under-treated acres (acres with a high need for conservation treatment) with water erosion control practices only.
2. Treatment of all 15.3 million under-treated acres (acres with a high or moderate need for conservation treatment) with water erosion control practices only.
3. Treatment of the 1.1 million critical under-treated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.
4. Treatment of all 15.3 million under-treated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.

In summary, the bulk of the potential field-level savings from conservation treatment, relative to losses simulated for the no-practice scenario, have been achieved in this region. The percent of potential savings represented by practices in use in 2003–06 are: 75 percent for sediment, 68 percent for nitrogen, and 76 percent for phosphorus. By treating all 15.3 million under-treated acres in the region with additional erosion control and nutrient management practices, an additional 10 percent in savings would be attained for sediment, 11 percent for nitrogen, and 9 percent for phosphorus. To achieve 100 percent of potential savings (i.e., an additional 15 percent for sediment and phosphorus and 21 percent for nitrogen), additional conservation treatment for the remaining 68.3 million acres with a low need for additional treatment would be required, which would result in very small conservation gains on a per-acre basis.

The specific conservation practices used in the simulated treatments are not intended to be a prescription for how to construct conservation plans, but rather are a general representation of sets or suites of conservation practices that could be used to address multiple resource concerns. In actual planning situations a variety of alternative practice scenarios would be presented to the producer and selections would be based on the level of treatment need, cost of conservation implementation, impact on production goals, and preferences of the farm operator.

In the derivation of conservation plans, other conservation practices would be considered, such as cover crops, tillage and residue management, conservation crop rotations, drainage water management, and emerging conservation technologies. Only erosion control structural practices and consistent nutrient management techniques were simulated here to serve as a proxy for the more comprehensive suite of practices that is obtained through the conservation planning process. For example, a conservation plan may include tillage and residue management and cover crops instead of some of the structural practices included in the model simulation. Similarly, drainage water management or cover crops might be used as a substitute for—or in addition to—strict adherence to the right rate, timing, and method of nutrient application.

Long-term conserving cover was not included in the treatment scenarios. Long-term conserving cover represents the ultimate conservation treatment for acres that are highly vulnerable to sediment and nutrient loss, but if it was widely used, regional crop production levels could not be maintained. Enrolling more cultivated cropland acres in programs that provide the economic incentives for long-term conserving cover may be necessary in some areas to meet water quality goals for environmental protection.

Pesticide management was also not addressed directly in the treatment scenarios. While erosion control practices influence pesticide transport and loss, significant reductions in pesticide edge-of-field environmental risk within the region will require more intensive Integrated Pest Management (IPM) practices, including pesticide substitutions. Simulation of additional IPM and any associated pesticide substitutions is site specific and requires more information about the sample fields than was available from the farmer survey.

The level of conservation treatment is simulated to show *potential* environmental benefits, but is not designed to achieve specific environmental protection goals.

Nor were treatment scenarios designed to represent actual program or policy options for the Missouri River Basin. Economic and programmatic aspects—such as producer costs, conservation program costs, and capacity to deliver the required technical assistance—were not considered in the assessment of the potential gains from further conservation treatment.

Simulation of Additional Erosion Control Practices

Treatment to control water erosion and surface water runoff consists of structural and vegetative practices that slow runoff water and capture contaminants that it may carry. Simulations of practices were added where needed (summarized in table 36) according to the following rules.

- **In-field mitigation:**
  - Terraces were added to all sample points with slopes greater than 6 percent, and to those with slopes greater than 4 percent *and* a high potential for excessive runoff (hydrologic soil groups C or D). Although terraces may be too expensive or impractical to implement in all cases, they serve here as a surrogate for other practices that control surface water runoff.
  - Contouring or stripcropping (overland flow practices) was added to all other fields with slope greater than 2 percent that did not already have those practices and did not have terraces.
  - Concentrated flow practices were not applied since they occur on unique landscape situations within the field; landscape data other than slope and slope length were not available for CEAP sample points.
- **Edge-of-field mitigation:**
  - Fields adjacent to water received a riparian buffer, if one was not already present.
  - Fields not adjacent to water received a filter strip, if one was not already present.

In addition, the implementation of structural and vegetative practices is simulated by an adjustment in the land condition parameter used to estimate the NRCS Runoff Curve Number (RCN). The RCN is an empirical parameter used in surface hydrology for predicting direct runoff or infiltration. The hydrologic condition (a component in the determination of the RCN) was adjusted from "poor" to "good" for sample points where these additional practices were simulated.

For additional wind erosion control, the proportion of the field protected from wind was increased. Practices such as windbreaks or shelterbelts, cross wind ridges, stripcropping or trap strips, and hedgerows are typically used for wind control. The effectiveness of these practices is simulated in the model by adjusting the unsheltered dimensions of the standard field that is modeled—a square field 400 meters (1,312 feet) on each side. For sample points where the wind erosion exceeded an average of 4 tons per acre per year in the baseline conservation condition (5,413,733 acres), wind erosion practices were added so as to reduce the unsheltered distance to 120 feet. This was typically achieved by adding cross-wind trap strips.

Table 36. Summary of additional structural practices for water erosion control simulated for under-treated acres to assess the potential for gains from additional conservation treatment in the Missouri River Basin

	Critical under-treated acres (acres with a high level of treatment need)		Non-critical under-treated acres (acres with a moderate level of treatment need)		All under-treated acres	
Additional practice	Treated acres	Percent of total	Treated acres	Percent of total	Treated acres	Percent of total
Overland flow practice only	0	0	0	0	0	0
Terrace only	0	0	15,823	0	15,823	0
Terrace plus overland flow practice	0	0	0	0	0	0
Filter only	339,559	30	6,805,944	48	7,145,503	47
Filter plus overland flow practice	88,696	8	1,655,471	12	1,744,167	11
Filter plus Terrace	436,410	39	2,525,866	18	2,962,276	19
Filter plus overland flow practice plus terrace	0	0	0	0	0	0
Buffer only	47,217	4	1,829,933	13	1,877,150	12
Buffer plus overland flow practice	0	0	434,556	3	434,556	3
Buffer plus Terrace	214,819	19	798,419	6	1,013,238	7
Buffer plus overland flow practice plus terrace	0	0	0	0	0	0
One or more additional practices	1,126,701	100	14,066,013	99	15,192,713	99
No structural practices added	0	0	113,358	1	113,358	1
Total	1,126,701	100	14,179,371	100	15,306,071	100

Note: Percents may not add to totals because of rounding

Simulation of Additional Nutrient Management Practices

The nutrient management treatment scenario consists of additional nutrient management practices where needed *in addition to* the erosion control practices. The nutrient management practices simulated the application of nutrients at an appropriate rate, in an appropriate form, at appropriate times, and using an appropriate method of application to provide sufficient nutrients for crop growth while minimizing losses to the environment. Simulation of nutrient management required changes to nutrient applications for one or more crops on all but about 7 percent of the acres (see table 10).

Specific rules for application timing

The goal for appropriate timing is to apply nutrients close to the time when the plant is likely to require them, thereby minimizing the opportunity for loss from the field. Rules for the timing of nutrient applications (both nitrogen and phosphorus) are:

- All commercial fertilizer applications were adjusted to 14 days prior to planting, except for acres susceptible to leaching loss.
- For acres susceptible to leaching loss (hydrologic soil group A, soils with sandy textures, or tile drained fields), nitrogen was applied in split applications, with 25 percent of the total application 14 days before planting and 75 percent 30 days after planting.
- Manure applications during winter months (December, January, February, and March) were moved to 14 days pre-plant or April 1, whichever occurs first. This rule allows for late March applications of manure in the warmer climates of the Missouri River Basin. April 1 is near the period when the soils warm and become biologically active. However, this late date could begin to pressure manure storage capacities and it is recognized that this could create storage problems.

In the baseline condition, about 25 percent of the cropped acres in the Missouri River Basin receive fertilizer applications in the fall for at least one spring-planted row crop in the rotation. The only fall application of nutrients simulated in the nutrient management treatment scenario was for fall seeded crops that received a starter fertilizer at planting time.

Specific rules for method of application

If the method of application was other than incorporation then in the simulations fertilizer and manure applications became incorporated or injected. Incorporation reduces the opportunity for nutrients on the soil surface to volatize or be carried away in soluble form or attached to eroding particles. For manure applications on no-till fields, if the manure was in liquid or slurry form and had been sprayed/broadcast applied it was changed to injected or placed under the soil surface. Manure of solid consistency was incorporated by disking without regard to the tillage management type. If the tillage type had been originally no-till, the incorporation of the manure changed the tillage type to mulch tillage.

Specific rules for the form of application

If the tillage type was no-till, commercial fertilizer was changed to a form that could be knifed or injected below the soil surface. The change in form did not change the ammonia or nitrate ratio of the fertilizer.

Specific rules for the rate of nutrients applied

Nitrogen application rates above 1.2 times the crop removal rate were reduced in the simulations to 1.2 times the crop removal rate for all crops except wheat and other small grain crops. The 1.2 ratio is in the range of rates recommended by many of the Land Grant Universities. This rate accounts for the savings in nutrients due to improved application timing and implementation of water erosion control practices and also replaces a reduced amount of environmental losses that occur during the cropping season.

For wheat and other small grain crops (barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale), nitrogen applications above 1.5 times the crop removal rate were reduced to 1.5 times the crop removal rate.

Phosphorus application rates above 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation were adjusted to be equal to 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation. Application rates for all phosphorus applications in the rotation were reduced in equal proportions.

Simulation of Irrigation Water Use Efficiency

Increases in the efficiency of irrigation water conveyances and water application were simulated in both the erosion control and the erosion control with nutrient management treatment scenarios. The volume of irrigation water used was simulated in the same manner as described for the baseline scenario in chapter 4. (Irrigation water was applied in the APEX model when a yield stress exceeded a specified threshold; the amount of irrigation water applied was determined by the amount of irrigation water required to fill the root-zone after accounting for conveyance losses.)

The treatment scenarios had four components.

1. The on-farm conveyance ditches were upgraded to pipelines.
2. Gravity systems and pressure systems were upgraded to center pivot or linear move sprinkler systems utilizing low-pressure sprinkler heads.[32]
3. Irrigation water management practices were simulated, which consisted of timing and rate of application adjustments designed to attain specified irrigation efficiencies.
4. Edge-of-field irrigation induced runoff was essentially eliminated on irrigated acres.

[32] An exception is in rice production areas where gravity systems are required to flood the fields. In these areas, grated pipe replaced ditches in the treatment simulations.

Implementation of the treatment scenario on all irrigated acres would result in an additional 6.2 million acres converted to center pivot or linear move sprinkler systems with low pressure heads.

In the Missouri River Basin, the representation of irrigation management in the treatment scenarios increased the average Virtual Irrigation System Efficiency (VISE) from 69 percent in the baseline conservation condition to 80 percent in the treatment scenarios. (As discussed in chapter 3, irrigation efficiencies were represented in APEX simulations as a combination of three different coefficients (losses at the head of the field, percolation losses, and end-of-field runoff) combined into a single efficiency value, VISE).

If all irrigated acres were treated, VISE would be increased by—

- 1-10 percent on 6.8 million acres (49 percent of irrigated acres),
- 10-20 percent on 4.2 million acres (36 percent),
- 20-30 percent on 1.2 million acres (10 percent), and
- 30-50 percent on 0.25 million acres (2 percent).

Emerging Technologies for Reducing Nutrient Losses from Farm Fields

The nutrient management simulated to assess the potential for further gains from conservation treatment represents traditional nutrient management techniques that have been in use for several years and would be expected to be found in current NRCS conservation plans. There are, however, emerging conservation technologies that have the potential to further reduce nutrient loss from farm fields and provide even greater crop use efficiencies once the technologies become more widespread. These include—

- Innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies;
- Enhanced-efficiency nutrient application products such as slow or controlled release fertilizers, polymer coated products, nitrogen stabilizers, urease inhibitors, and nitrification inhibitors;
- Drainage water management that controls discharge of drainage water and provides treatment of contaminants, thereby reducing the levels of nitrogen and even some soluble phosphorus loss; and
- Constructed wetlands receiving surface water runoff or drainage water from farm fields prior to discharge to streams and rivers.
- Use of riparian corridors for treating drainage water.

New technologies that have the potential to increase crop yields without increasing nutrient inputs could further improve crop nutrient use efficiency and reduce offsite transport of nutrients relative to the level of crop production.

Potential for Field-Level Gains

Treatment of the 1.1 million critical under-treated acres

Average annual model output is presented in table 37 for the 1.1 million critical under-treated acres (acres with a high level of treatment need). The baseline results for these acres are contrasted to model output for the two treatment simulations in that table. According to the model simulation, treatment of these acres with erosion control practices would nearly eliminate sediment loss and reduce wind erosion to an average of 1.1 tons per acre per year for the treated acres. Nitrogen loss with surface runoff would be reduced to 3.9 pounds per acre per year on average (80-percent reduction), and phosphorus lost to surface water would be reduced to 1.2 pounds per acre per year (74-percent reduction).

However, the re-routing of surface water to subsurface flow pathways would *increase* nitrogen loss in subsurface flows by 4 percent, on average, for these treated acres.

The addition of nutrient management would have little additional effect on wind erosion, sediment loss, or nitrogen loss with surface runoff, but would be effective in reducing nitrogen loss in subsurface flows and further reducing phosphorus lost to surface water (table 37). Nitrogen loss in subsurface flows for these acres would be reduced to an average of 10.3 pounds per acre per year, representing a 52-percent reduction compared to losses simulated for the baseline conservation condition. Phosphorus lost to surface water would be reduced to an average of 1.0 pound per acre per year.

These results support the conclusion drawn from the assessment of the effects of conservation practices in chapter 4 that nutrient management practices need to be paired with erosion control practices to attain significant reductions in the loss of soluble nutrients from cropped fields.

Treatment of all 15.3 million under-treated acres

Average annual model output is presented in table 38 for the treatment of all 15.3 million under-treated acres (acres with a high or moderate level of treatment need). The 15.3 million under-treated acres include 14.2 million acres with a moderate need for treatment that are less vulnerable or have more conservation practice use than the critical under-treated acres and therefore the potential for gains with additional treatment is less for those acres. Thus, table 38 shows that per-acre percent reductions of sediment and nutrient loss due to additional practices would generally be less, on average, than percent reductions for the 1.1 million most vulnerable under-treated acres.

Nonetheless, the per-acre gains from additional treatment of these acres would be substantial. Treatment with both erosion control and nutrient management would, compared to the baseline results for these acres—

- reduce average annual sediment loss from 0.6 ton per acre for the baseline to less than 0.1 ton per acre,
- reduce average wind erosion from 2.8 tons per acre per year to 1.5 tons per acre per year,
- reduce average annual nitrogen loss with surface runoff (including waterborne sediment) from 4 pounds per acre to less than 1 pound per acre,
- reduce average annual nitrogen loss in subsurface flows from 10 pounds per acre to about 6 pounds per acre,
- reduce total nitrogen loss (all loss pathways, including wind erosion) from 32 pounds per acre per year to 19 pounds per acre per year, and
- reduce total phosphorus loss (all loss pathways, including wind erosion) from 3.0 pounds per acre per year to 1.4 pounds per acre, per year, for these acres.

Diminishing returns from additional conservation treatment

Per-acre gains from additional conservation treatment are highest for the more vulnerable and less treated acres than for the less vulnerable and more treated acres. These “diminishing returns” to additional treatment indicate that targeting treatment to the acres with the greatest need is an efficient way to reduce agricultural sources of contaminants from farm fields within the basin.

Table 39 contrasts the per-acre model simulation results for additional erosion control and nutrient management on three subsets of acres in the Missouri River Basin—

1. the 1.1 million under-treated acres with a “high” need for additional treatment,
2. the 14.2 million under-treated acres with a “moderate” need for additional treatment, and
3. the 68.3 million acres with a “low” need for additional treatment.

Diminishing returns from additional conservation treatment is demonstrated by comparing the average annual per-acre reductions in losses among the three groups of acres.

For example, conservation treatment of the 1.1 million critical under-treated acres would reduce sediment loss by an average of 2.9 tons per acre per year on those acres. In comparison, additional treatment of the 14.2 million acres with a moderate need for treatment would reduce sediment loss by about 0.3 ton per acre per year on those acres. Treatment of the remaining 68.3 million acres would reduce sediment loss by less than 0.2 ton per acre, on average.

Similarly, diminishing returns would be pronounced for nitrogen and phosphorus loss. Total nitrogen loss would be reduced by an average of 31.4 pounds per acre per year on the 1.1 million critical under-treated acres, compared to a reduction of 12.2 pounds per acre for the 14.2 million under-treated acres with a moderate need for treatment, and only 5.8 pounds per acre for the remaining 68.3 million acres.

Nitrogen loss in subsurface flows would be reduced by an average of 11.1 pounds per acre per year on the 1.1 million critical under-treated acres, compared to a reduction of 3.9 pounds per acre for the 14.2 million acres with a moderate need for treatment. The reduction from treatment of the remaining 68.3 million acres would average only 1.7 pounds per acre.

Table 37. Conservation practice effects for additional treatment of 1.1 million critical under-treated acres (acres with a *high* need for conservation treatment) in the Missouri River Basin

	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
Model simulated outcome	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	3.0	2.4	21%	2.4	20%
Subsurface water flow (inches)	6.2	6.5	-4%	6.5	-5%
Erosion and sediment loss					
Wind erosion (tons/acre)	1.97	1.13	43%	1.16	41%
Sheet and rill erosion (tons/acre)	2.64	0.82	69%	0.81	69%
Sediment loss at edge of field due to water erosion (tons/acre)	3.10	0.16	95%	0.16	95%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-59	42	--	41	--
Nitrogen					
Nitrogen applied (pounds/acre)	100	97*	3%	74	26%
Nitrogen in crop yield removed at harvest (pounds/acre)	103	100	2%	96	6%
Total nitrogen loss for all loss pathways (pounds/acre)	58.1	42.2	27%	26.7	54%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	19.3	3.9	80%	3.5	82%
Nitrogen loss in subsurface flows (pounds/acre)	21.4	22.3	-4%	10.3	52%
Phosphorus					
Phosphorus applied (pounds/acre)	27.2	26.5*	2%	24.0	11%
Total phosphorus loss for all loss pathways (pounds/acre)	7.96	3.53	56%	3.05	62%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	4.80	1.25	74%	1.01	79%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	13	6	55%	6	55%
Surface water pesticide risk indicator for aquatic ecosystems	2.58	2.21	14%	2.21	14%
Surface water pesticide risk indicator for humans	0.59	0.47	20%	0.47	21%

* Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.

Note: Values reported in this table are for the 1.1 million critical under-treated acres only. Percent reductions are with respect to the baseline conservation condition.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 38. Conservation practice effects for additional treatment of all 15.3 million under-treated acres (acres with a *high* or *moderate* need for conservation treatment) in the Missouri River Basin

Model simulated outcome	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	1.1	0.8	24%	0.9	24%
Subsurface water flow (inches)	3.1	3.0	3%	3.0	2%
Erosion and sediment loss					
Wind erosion (tons/acre)	2.84	1.46	49%	1.46	49%
Sheet and rill erosion (tons/acre)	0.54	0.19	65%	0.18	66%
Sediment loss at edge of field due to water erosion (tons/acre)	0.56	0.03	95%	0.03	95%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-44	1	--	-2	--
Nitrogen					
Nitrogen applied (pounds/acre)	70	68*	3%	56	19%
Nitrogen in crop yield removed at harvest (pounds/acre)	70	68	2%	66	6%
Total nitrogen loss for all loss pathways (pounds/acre)	32.2	25.1	22%	18.6	42%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	4.2	0.9	78%	0.8	81%
Nitrogen loss in subsurface flows (pounds/acre)	10.1	10.2	-1%	5.7	44%
Phosphorus					
Phosphorus applied (pounds/acre)	14.2	14.2*	0%	12.7	11%
Total phosphorus loss for all loss pathways (pounds/acre)	3.01	1.54	49%	1.36	55%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	1.01	0.33	67%	0.26	74%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	4	2	49%	2	48%
Surface water pesticide risk indicator for aquatic ecosystems	1.40	0.86	38%	0.86	38%
Surface water pesticide risk indicator for humans	0.23	0.17	26%	0.17	25%

* Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.

Note: Values reported in this table are for the 15.3 million under-treated acres only. Percent reductions are with respect to the baseline conservation condition.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 39. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices for three groups of acres comprising the 83.6 million cropped acres in the Missouri River Basin

	Additional treatment for 1.1 million critical under-treated acres*			Additional treatment for 14.2 million non-critical under-treated acres*			Additional treatment for remaining 68.3 million acres		
	Baseline	Treatment scenario		Baseline	Treatment scenario		Baseline	Treatment scenario	
	Average annual amount	Average annual amount	Reduction	Average annual amount	Average annual amount	Reduction	Average annual amount	Average annual amount	Reduction
Water flow									
Surface water runoff (inches)	3.0	2.4	0.6	1.0	0.7	0.2	1.4	1.1	0.3
Subsurface water flow (inches)	6.2	6.5	-0.3	2.9	2.8	0.1	3.1	3.2	-0.1
Erosion and sediment loss									
Wind erosion (tons/acre)	1.97	1.16	0.81	2.91	1.49	1.42	0.74	0.55	0.19
Sheet and rill erosion (tons/acre)	2.64	0.81	1.83	0.37	0.13	0.24	0.26	0.11	0.16
Sediment loss at edge of field due to water erosion (tons/acre)	3.10	0.16	2.94	0.35	0.02	0.34	0.20	0.02	0.18
Soil organic carbon									
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-59	41	100**	-42	-6	37**	74	82	9**
Nitrogen									
Nitrogen applied (pounds/acre)	100	74	26	68	55	12	64	55	10
Nitrogen in crop yield removed at harvest (pounds/acre)	103	96	6	68	64	4	78	74	4
Total nitrogen loss for all loss pathways (pounds/acre)	58.1	26.7	31.4	30.2	18.0	12.2	21.4	15.6	5.8
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	19.3	3.5	15.9	3.0	0.6	2.4	2.2	0.7	1.5
Nitrogen loss in subsurface flows (pounds/acre)	21.4	10.3	11.1	9.3	5.4	3.9	6.2	4.5	1.7
Phosphorus									
Phosphorus applied (pounds/acre)	27.2	24.0	3.11	13.2	11.8	1.37	14.2	12.8	1.37
Total phosphorus loss for all loss pathways (pounds/acre)	7.96	3.05	4.91	2.62	1.22	1.39	1.42	0.85	0.57
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	4.80	1.01	3.79	0.71	0.20	0.50	0.59	0.25	0.35
Pesticide loss									
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	13	6	7.4	3	2	1.3	3	2	1.2
Surface water pesticide risk indicator for aquatic ecosystem	2.58	2.21	0.37	1.30	0.76	0.55	1.32	1.03	0.28
Surface water pesticide risk indicator for humans	0.59	0.47	0.12	0.20	0.15	0.05	0.27	0.21	0.06

*Critical under-treated acres have a high need for additional treatment. Non-critical under-treated acres have a moderate need for additional treatment.
** Gain in soil organic carbon.

Total phosphorus loss would be reduced by an average of 4.9 pounds per acre per year on the 1.1 million critical under-treated acres, compared to a reduction of 1.4 pounds per acre for the 14.2 million under-treated acres with a moderate need for treatment and only 0.6 pound per acre for the remaining 68.3 million acres.

Some diminishing returns for reduction in environmental risk for pesticides are also evident, in spite of the fact that pesticide risk was not taken into account in the identification of under-treated acres and the assessment of conservation treatment needs.

(This rudimentary assessment of diminishing returns ignores the cost of treatment and is focused only on reducing edge-of-field losses. If the cost of treatment for the critical under-treated acres is substantially greater than for the non-critical under-treated acres, the optimal strategy would be to treat a mix of critical and non-critical under-treated acres so as to maximize total edge-of-field savings for a given level of expenditure. If the objective of the conservation treatment was specifically to protect water quality, the relative environmental benefits of sediment and nutrient reductions would need to also be considered, as well as any edge-of-field loss thresholds that would need to be met to achieve local water quality goals.)

Estimates of edge-of-field sediment and nutrient savings due to use of conservation practices

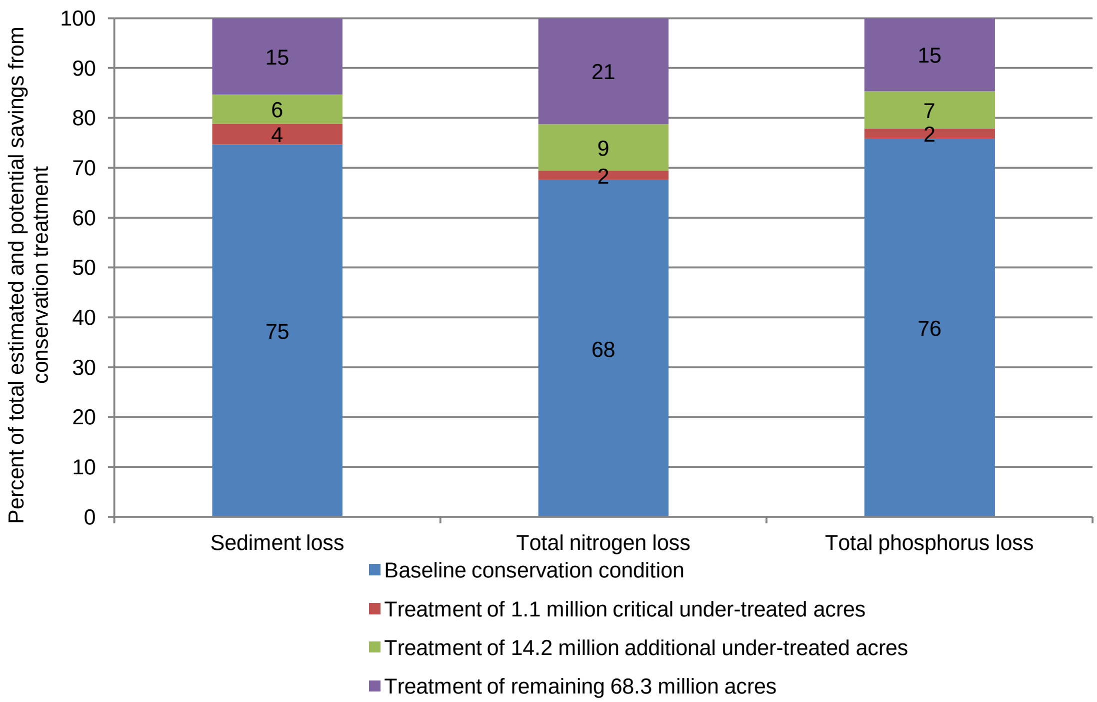
Potential sediment and nutrient savings from additional conservation treatment are contrasted to estimated savings for the conservation practices in use in 2003–06 in figure 77. The no-practice scenario represents the maximum losses that would be expected without any conservation practices in use. Treatment of *all acres* with nutrient management and erosion control practices was used to represent a "full-treatment" condition. The difference in sediment and nutrient loss between these two scenarios represents the maximum savings possible for conservation treatment, which totaled 80.2 million tons of sediment, 930,224 tons of nitrogen, and 132,694 tons of phosphorus for the Missouri River Basin (fig. 77).

For sediment loss, about 75 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition (fig. 77). Additional treatment of the 1.1 million critical under-treated acres would account for another 4 percent of the potential sediment savings. Treatment of the 14.2 million under-treated acres with a moderate need for treatment would account for about 6 percent of the potential savings. Treatment of the 68.3 million adequately treated acres would account for the last 15 percent of potential savings.

The proportions of savings from existing practices and with additional conservation treatment are about the same for phosphorus.

The proportions of savings from existing practices for nitrogen are slightly smaller—about 68 percent of the potential savings are accounted for by the conservation practices already in use. Correspondingly, there is somewhat more opportunity to reduce nitrogen losses with additional conservation treatment in this region (fig. 77), although the bulk of it—21 percent—requires additional treatment for acres with a low need for additional treatment.

Figure 77. Comparison of estimated sediment, nitrogen, and phosphorus savings (field-level) that are due to practices in use in the baseline conservation condition and potential savings with additional water erosion control *and* nutrient management treatment of cropped acres in the Missouri River Basin



Sediment, nitrogen, and phosphorus saved or potentially saved due to conservation practices

	Estimated savings due to conservation practice use (baseline conservation condition)	Potential savings from treatment of 1.1 million critical under-treated acres*	Potential savings from treatment of 14.2 million additional under-treated acres*	Potential savings from treatment of remaining 68.3 million acres*	Total estimated and potential savings from conservation treatment
Sediment (tons)	59,914,066	3,311,107	4,759,238	12,261,017	80,245,428
Nitrogen (tons)	628,131	17,709	86,593	197,791	930,224
Phosphorus (tons)	100,583	2,765	9,878	19,468	132,694

*Treatment with erosion control practices and nutrient management practices on all cropped acres.

Note: Calculations do not include land in long-term conserving cover.

Note: Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

Expected regional results assuming all under-treated acres were treated

Even though under-treated acres represent less than one in five of the cropped acres in this region, important reductions in soil and nutrient loss from farm fields could be achieved with additional conservation treatment. Table 40 summarizes the effects that would be expected if all 15.3 million acres were treated with erosion control practices alone or with erosion control and nutrient management practices under the assumptions of those two treatment scenarios. Results are presented in table 40 for the region as a whole by combining model output simulating additional treatment for the 15.3 million under-treated acres with unchanged model output for the remaining 68.3 million acres from the baseline simulation.

Compared to the baseline conservation condition, treating the 15.3 million under-treated acres (18 percent of cropped acres in the region) with soil erosion control practices *and* nutrient management practices would, for the region as a whole—

- reduce sediment loss averaged over all cropped acres in the region by 37 percent;
- reduce wind erosion averaged over all cropped acres in the region by 22 percent,
- reduce total nitrogen loss averaged over all cropped acres in the region by 11 percent:
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) averaged over all cropped acres in the region by 24 percent, and
  - reduce nitrogen loss in subsurface flows averaged over all cropped acres in the region by 12 percent;
- reduce phosphorus lost to surface water averaged over all cropped acres in the region by 20 percent; and
- reduce environmental risk from loss of pesticide residues averaged over all cropped acres in the region by 4 to 7 percent.

Nearly all of these reductions in sediment loss, wind erosion, nitrogen lost with surface water, phosphorus lost to surface water, and environmental risk from loss of pesticide residues are due to the erosion control practices, as shown in table 40. The additional nutrient management practices accounted for all of the reduction in nitrogen loss in subsurface flows, reducing the annual loss from about 7 pounds per acre to 6 pounds per acre averaged over all of the 83.6 million acres in the region.

The effects of treating the 15.3 million acres for the region as a whole are graphically shown in figures 78 through 85. In these figures the model results for the baseline distribution are contrasted with the distribution of model results for additional treatment of under-treated acres with erosion control and nutrient management practices. Results for two additional scenarios are also shown for perspective: 1) the no-practice scenario, and 2) treatment of *all* acres with erosion control and nutrient management practices, including the 68.3 million acres with a "low" treatment need.

Model simulations indicate that for wind erosion the percentage of acres exceeding 4 tons per acre per year, the "acceptable level" used in chapter 5 as part of the process to identify under-treated acres, would be reduced from 6.5 percent in the baseline to 3.4 percent after treating the 15.3 million undertreated acres (fig. 78). For sediment loss (fig. 79), the percentage of acres exceeding 2 tons per acre per year would be reduced from 2.5 percent in the baseline to 0.8 percent.

Figure 80 shows that the distribution of soil organic carbon is affected little by additional soil erosion control and nutrient management practices for under-treated acres in the region. Increases in soil organic carbon were generally restricted to acres losing more than 100 pounds per acre in the baseline scenario.

The effect of additional conservation treatment for under-treated acres on nitrogen loss is shown in figures 81–83. For nitrogen lost with surface runoff, the percentage of acres exceeding 15 pounds per acre per year would be reduced from 3.4 percent in the baseline to 1.4 percent (fig. 81). For nitrogen loss in subsurface flows, the percentage of acres exceeding 25 pounds per acre per year would be reduced from 4.6 percent in the baseline to 3.4 percent (fig. 82). Reductions in total nitrogen loss, which also includes nitrogen loss with windborne sediment, nitrogen volatilization, and denitrification, would be reduced by larger amounts, as shown in figure 83.

Similar results were found for phosphorus lost to surface water; the percentage of acres exceeding 4 tons per acre per year would be reduced from 3.0 percent in the baseline to 1.4 percent (fig. 84) by treating the 15.3 million under-treated acres.

Figure 85 shows the effects of irrigation water use on irrigated acres in the Missouri River Basin. The gap between the curves for the baseline conservation condition and the no-practice scenario reflects the movement away from less efficient ditches and gravity irrigation used in the past to more efficient pressure irrigation systems. Treatment of the 15.3 million acres with a high or moderate need for additional soil erosion control or nutrient management would reduce irrigation water use somewhat. However, treatment of all irrigated acres would be required to significantly reduce irrigation water use (fig. 85). Implementing the treatment scenario on all irrigated acres would reduce irrigation water use by an average of 2.2 inches per acre per year, compared to the baseline. This reduced water requirement represents 2.1 million acre feet per year.

One of the objectives in constructing the treatment scenarios was to maintain the level of regional crop production. The removal of nitrogen at harvest serves as a useful proxy for crop yields and allows for aggregation over the mix of crops. As shown in figure 86, the distribution of nitrogen removed at harvest is about the same for the curve representing the baseline scenario and the curve representing additional treatment of 15.3 million under-treated acres. A reduction in yield for the region as a whole would occur, however, if the 68.3 acres with a "low" need for additional treatment were also treated, as shown by the curve in figure 86 representing the treatment of *all* acres.

Table 40. Conservation practice effects for the region as a whole* after additional treatment of 15.3 million under-treated acres (acres with a *high* or *moderate* need for conservation treatment) in the Missouri River Basin

	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
Model simulated outcome	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	1.3	1.3	4%	1.3	4%
Subsurface water flow (inches)	3.1	3.1	1%	3.1	0%
Erosion and sediment loss					
Wind erosion (tons/acre)	1.13	0.87	23%	0.87	22%
Sheet and rill erosion (tons/acre)	0.31	0.25	21%	0.25	21%
Sediment loss at edge of field due to water erosion (tons/acre)	0.26	0.17	37%	0.17	37%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	52	61	--	60	--
Nitrogen					
Nitrogen applied (pounds/acre)	65	65	1%	63	4%
Nitrogen in crop yield removed at harvest (pounds/acre)	76	76	0%	76	1%
Total nitrogen loss for all loss pathways (pounds/acre)	23.4	22.1	6%	20.9	11%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	2.6	2.0	23%	2.0	24%
Nitrogen loss in subsurface flows (pounds/acre)	6.9	6.9	0%	6.1	12%
Phosphorus					
Phosphorus applied (pounds/acre)	14.2	14.2	0%	13.9	2%
Total phosphorus loss for all loss pathways (pounds/acre)	1.71	1.45	16%	1.41	18%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	0.67	0.55	19%	0.53	20%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	3	3	10%	3	10%
Surface water pesticide risk indicator for aquatic ecosystems	1.33	1.23	7%	1.23	7%
Surface water pesticide risk indicator for humans	0.26	0.25	4%	0.25	4%

* Results presented for the region as a whole combine model output for the 15.3 million treated acres with model results from the baseline conservation condition for the remaining acres.
Note: Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 78. Estimates of average annual wind erosion for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Missouri River Basin

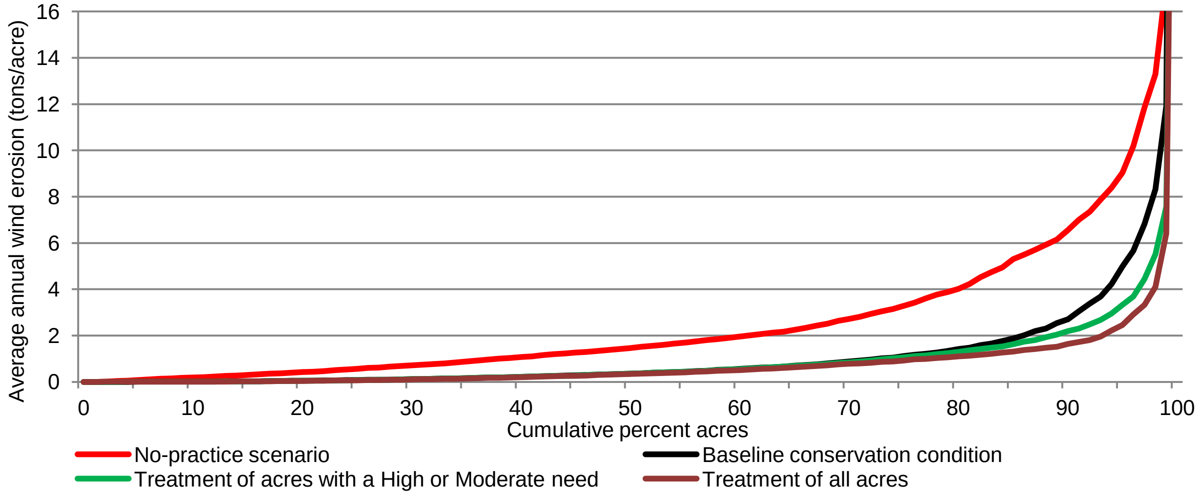


Figure 79. Estimates of average annual sediment loss for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Missouri River Basin

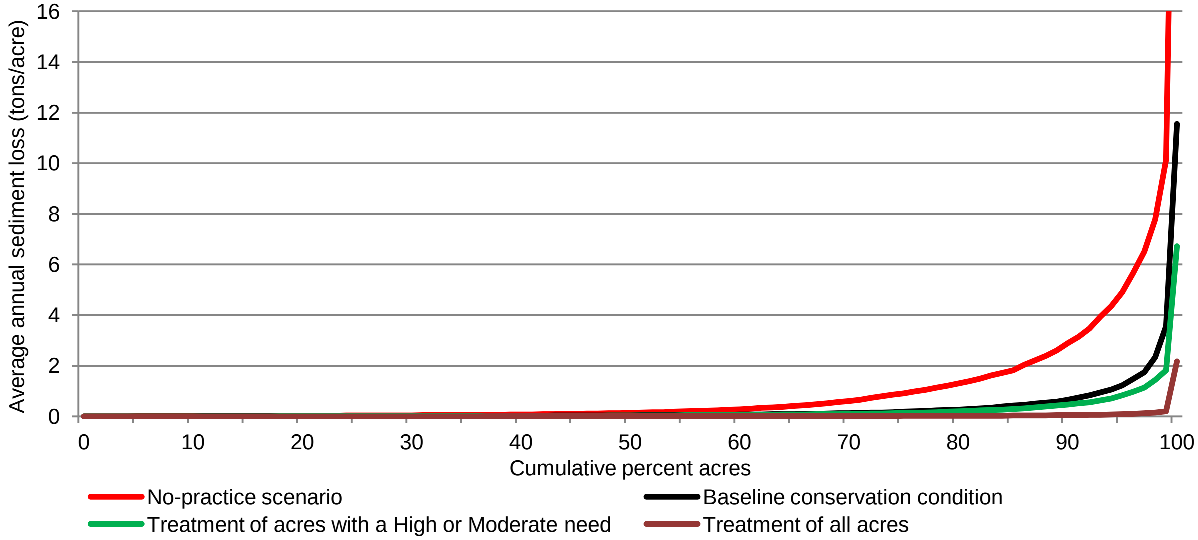


Figure 80. Estimates of average annual change in soil organic carbon for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Missouri River Basin

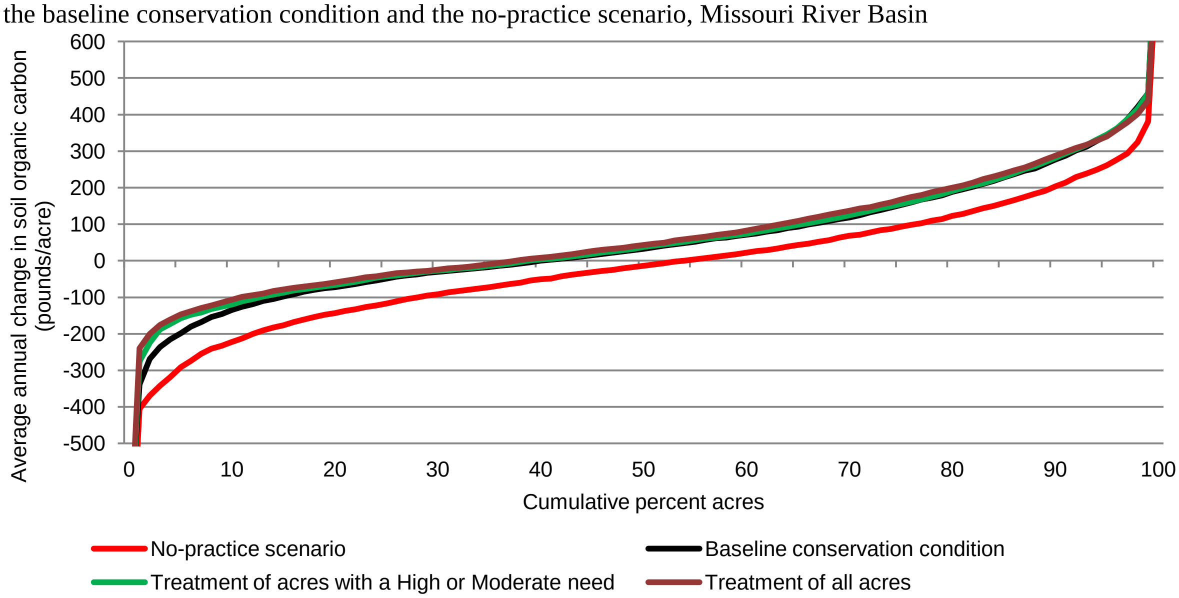


Figure 81. Estimates of average annual loss of nitrogen with surface runoff for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Missouri River Basin

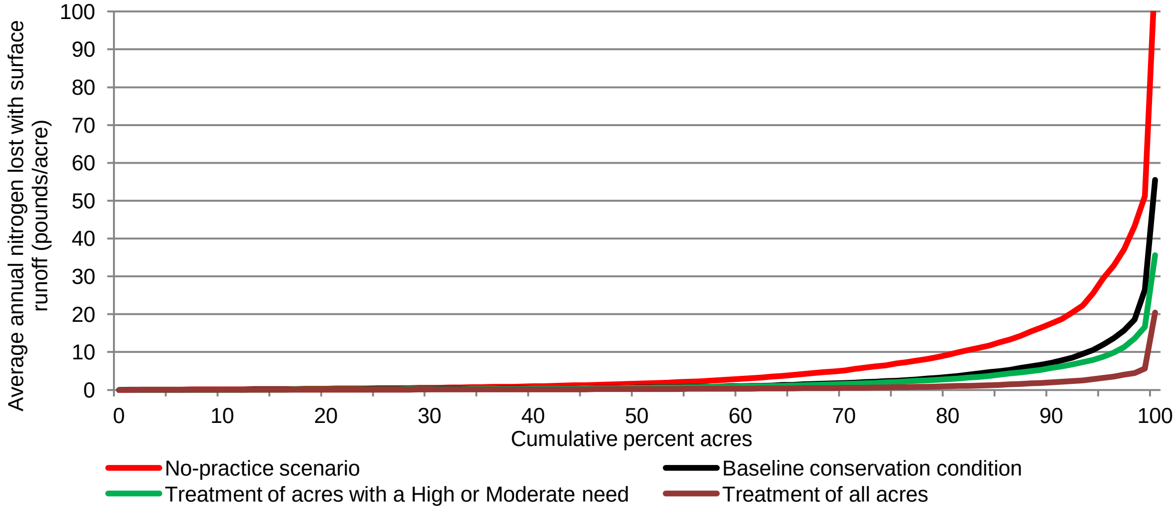


Figure 82. Estimates of average annual loss of nitrogen in subsurface flows for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Missouri River Basin

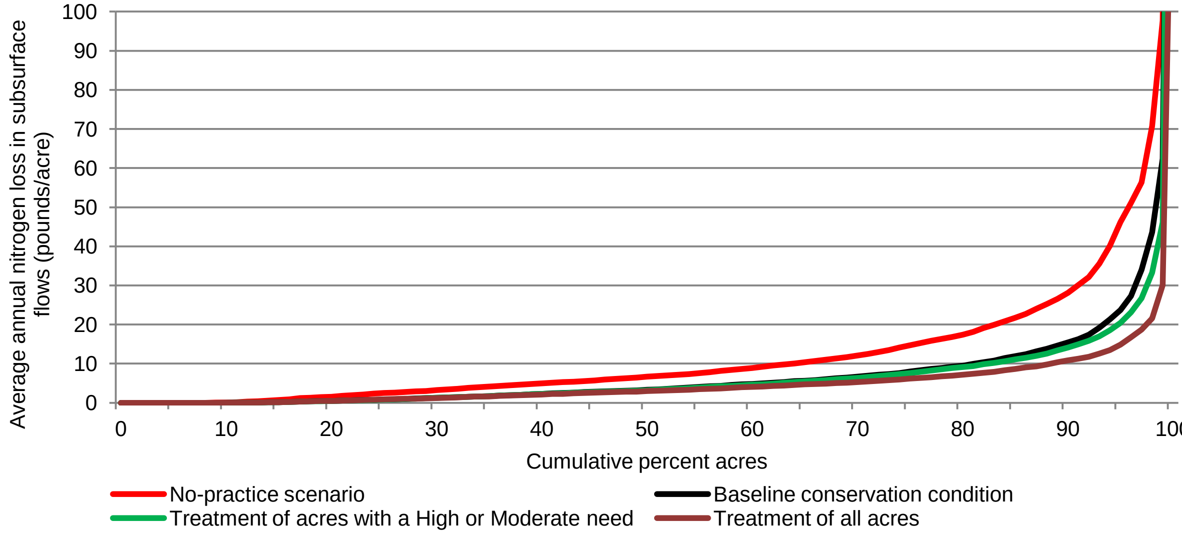


Figure 83. Estimates of average annual total nitrogen loss for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Missouri River Basin

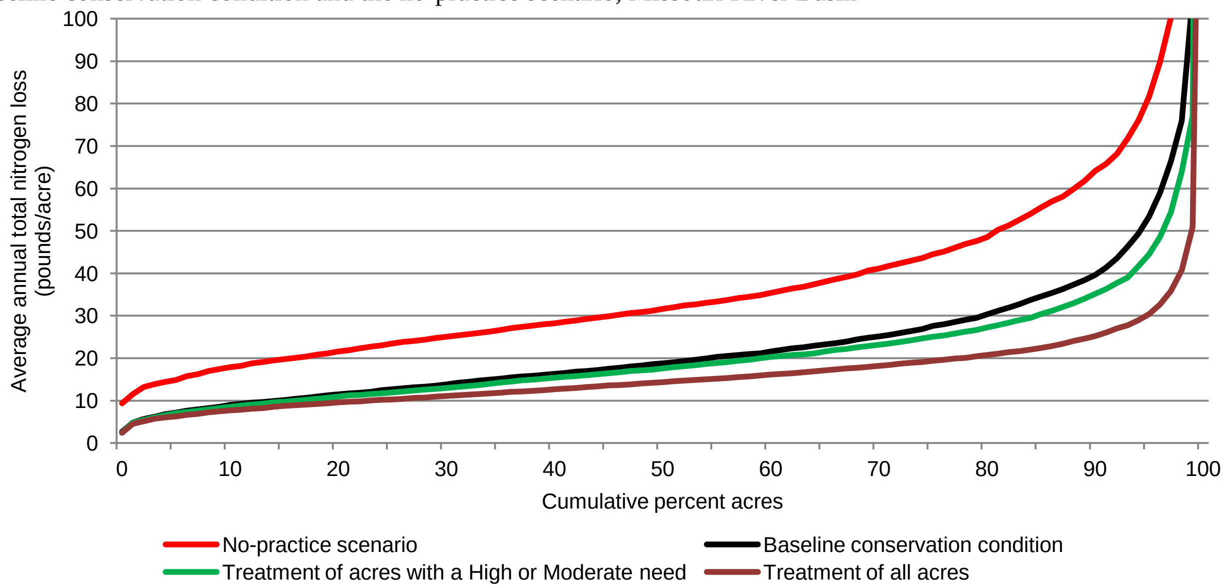
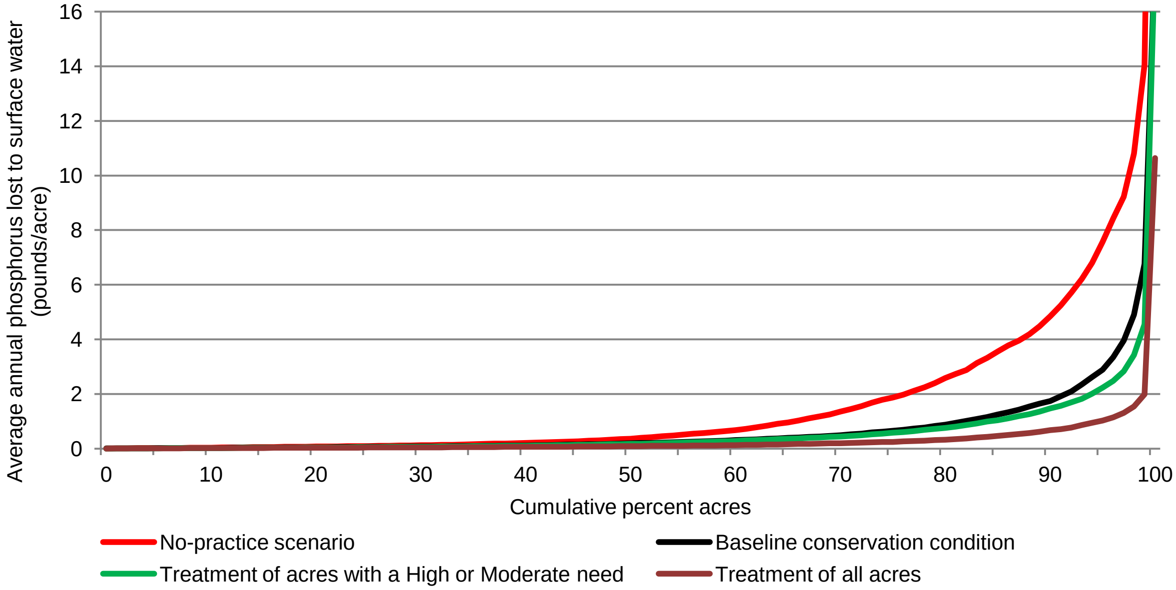


Figure 84. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Missouri River Basin



* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

Figure 85. Estimates of average annual irrigation water application for the treatment scenarios compared to the baseline conservation condition and the no-practice scenarios, Missouri River Basin

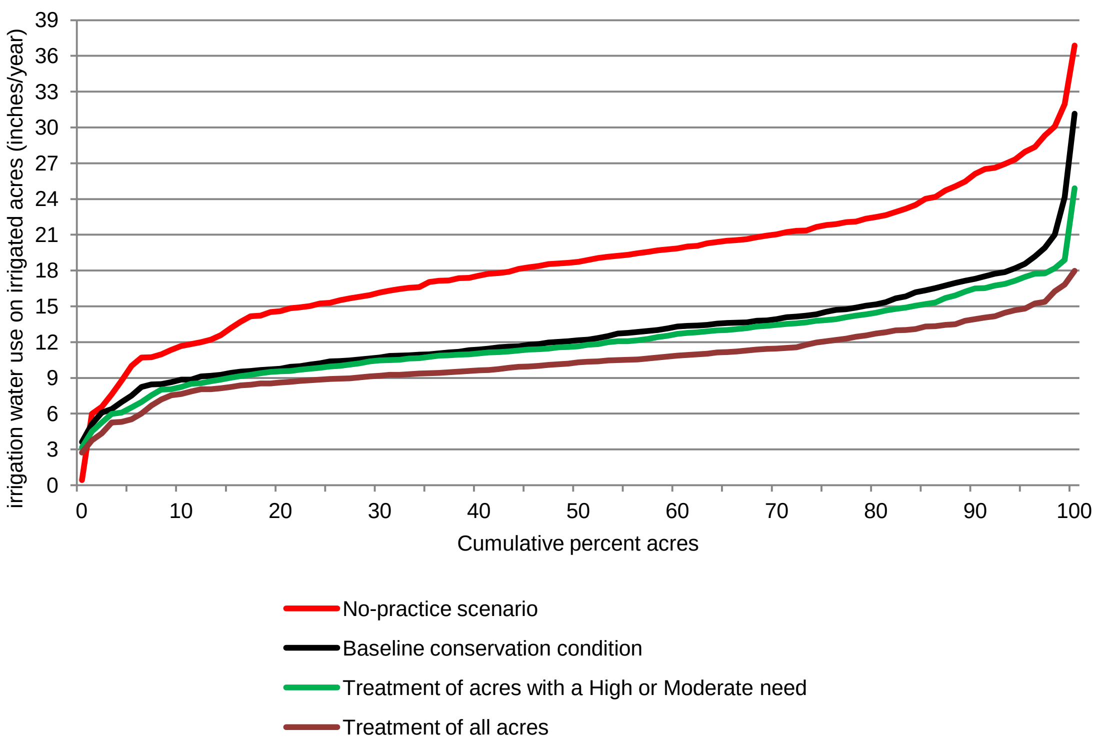
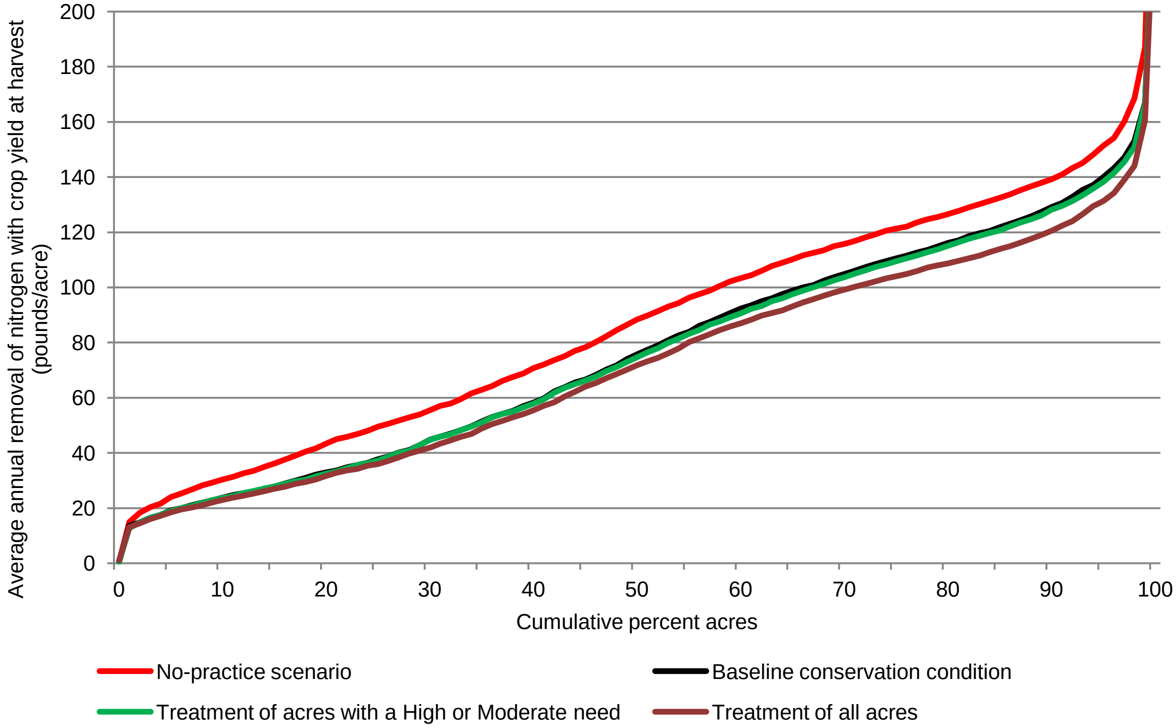


Figure 86. Estimates of average annual removal of nitrogen with crop yield at harvest for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Missouri River Basin



Chapter 7
Offsite Water Quality Effects of Conservation Practices

Field-level losses of sediment, nutrients, and atrazine estimated using APEX were integrated into a large-scale water quality model to estimate the extent to which conservation practices reduce—

- loads delivered to rivers and streams within the basin,
- instream loads at various points within the basin, and
- loads exported from the region to the Mississippi River.

Loading estimates are generally reported for each of the 29 subregions (4-digit hydrologic unit code) in the Missouri River Basin, shown in figure 87. However, results for subregions with few acres of cultivated cropland are aggregated with other subregions for reporting because the CEAP sample had too few observations to report results separately.

Aggregated results are reported for 6 of the 29 subregions, as shown in the table below:

Aggregation used for reporting	Subregion code
Missouri Headwaters and Upper Missouri-Marias	
Missouri Headwaters subregion	1002
Upper Missouri-Marias Rivers subregion	1003
Big Horn and Powder-Tongue River Basins	
Big Horn River subregion	1008
Powder-Tongue Rivers subregion	1009
Cheyenne and Missouri-Grand-Moreau-Lake Oahe	
Cheyenne River subregion	1012
Missouri-Grand-Moreau-Lake Oahe subregion	1013

Results for subregion 1001 are not reported. This is a very small area (700 square miles) near the Canadian border that actually flows north to the Saskatchewan River.

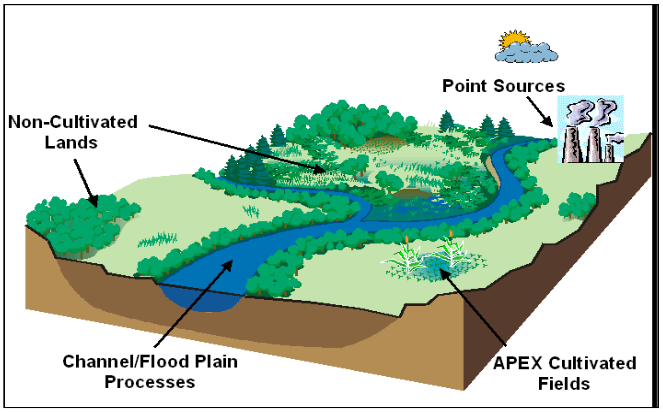
Canadian portions of the Missouri River drainage were not modeled; loading estimates are for the United States portion of the drainage system.

Figure 87. Subregions (4-digit HUC groupings of 8-digit HUCs) within the Missouri River Basin

The National Water Quality Model—HUMUS/SWAT

Offsite estimates of water quality benefits were assessed using HUMUS/SWAT, a combination of the SWAT model and HUMUS (Hydrologic Unit Modeling for the United States) databases required to run SWAT at the watershed scale for all watersheds in the United States (Arnold et al. 1999; Srinivasan et al. 1998). SWAT simulates the transport of water, sediment, nutrients, and pesticides and from the land to receiving streams and the flow downstream to the next watershed and ultimately to estuaries and oceans (fig. 88).

Figure 88. Sources of water flows, sediment, and agricultural chemicals simulated with HUMUS/SWAT



Like APEX, SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007).[33] The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

Upland processes

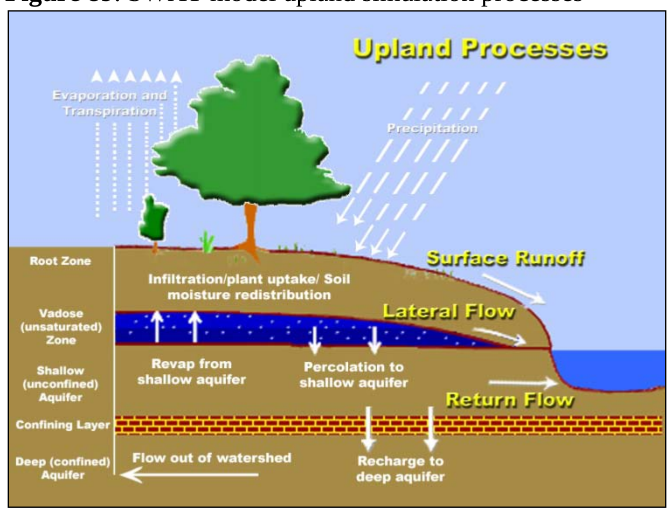
The water balance is the driving force for transport and delivery of sediment, nutrients, and pesticides from fields to streams and rivers. For this study, upland processes for non-cultivated cropland were modeled using SWAT, while source loads for cultivated cropland are estimated by APEX.

In SWAT, each watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, management, and slope. An HRU is not a contiguous land area, but rather represents the percentage of the watershed that has the HRU characteristics. In this study, SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides for the following land use categories, referred to as HRUs:

- Pastureland
- Permanent hayland
- Range shrub
- Range grass
- Urban
- Mixed forest
- Deciduous forest
- Evergreen forest
- Horticultural lands
- Forested wetlands
- Non-forested wetlands

Upland processes were modeled for each of these HRUs in each watershed (8-digit HUC) (fig. 89). The model simulates surface runoff estimated from daily rainfall; percolation modeled with a layered storage routing technique combined with a subsurface flow model; lateral subsurface flow; groundwater flow to streams from shallow aquifers; potential evapotranspiration; snowmelt; transmission losses from streams; and water storage and losses from ponds.

Figure 89. SWAT model upland simulation processes



Agricultural Sources

Upland processes for cultivated cropland (including land in long-term conserving cover) were modeled using APEX as described in previous chapters. The weighted average of per-acre APEX model output for surface water delivery, sediment, nutrients, and pesticides was multiplied by the acres of cultivated cropland in the HUMUS database and used as SWAT model inputs for cultivated cropland for each 8-digit Hydrologic Unit Code (HUC). The acreage weights for the CEAP sample points were used to calculate the per-acre loads. (Several of the 8-digit watersheds in each region had too few CEAP sample points to reliably estimate edge-of-field per-acre loads. In these cases, the 6-digit per acre loads and sometimes the 4-digit per-acre loads were used to represent cultivated cropland.)

Various types of agricultural land management activities were modeled in SWAT for land use categories other than cultivated cropland. For permanent hayland, the following management activities were simulated:

[33] A complete description of the SWAT model can be found at http://www.brc.tamus.edu/swat/index.html.

- Hay was fertilized with nitrogen according to the crop need as determined by an auto-fertilization routine, which was set to grow the crop without undue nitrogen stress.
- Legume hay was grown in a 4-year rotation and phosphorus was applied at the time of planting (every fourth year) at a rate of 50 pounds per acre, followed by applications of 13 pounds per acre every other year.
- Manure was applied to 2 percent of the hayland acres at rates estimated from probable land application of manure from animal feeding operations, estimated using the methods described in USDA/NRCS (2003). These calculations indicated that 2 percent of hayland acres in the Missouri River Basin could have received manure from animal feeding operations.
- Three hay cuttings were simulated per crop year for grass hay and four hay cuttings were simulated per year for legume hay.
- For hayland acres that land-use databases indicated were irrigated, water was applied at a frequency and rate defined by an auto-irrigation routine.

For pastureland and rangeland, the following management activities were simulated:

- Continuous grazing was simulated by algorithms that determined the length of the grazing period, amount of biomass removed, and the amount of biomass trampled. Grazing occurs whenever the plant biomass is above a specified minimum plant biomass for grazing. The amount of biomass trampled daily is converted to residue.
- Manure nutrients from grazing animals were simulated for pastureland and rangeland according to the density of grazing livestock as reported in the 2002 Census of Agriculture. Non-recoverable manure was estimated by subtracting recoverable manure available for land application from the total manure nutrients representing all livestock populations. Non-recoverable manure nutrients include the non-recoverable portion from animal feeding operations. Estimates of manure nutrients were derived from data on livestock populations as reported in the 2002 Census of Agriculture, which were available for each 6-digit HUC and distributed among the 8-digit HUCs on a per-acre basis.
- Manure was applied to 0.6 percent of pastureland acres at rates estimated from probable land application of manure obtained from animal feeding operations as estimated in USDA/NRCS (2003). These calculations indicated that 0.6 percent of pastureland acres in the Missouri River Basin could have received manure from animal feeding operations.
- Supplemental commercial nitrogen fertilizers were applied to pastureland according to the crop need as determined by an auto-fertilization routine, which was set to grow grass without undue nitrogen stress.

Horticulture land was fertilized with 100 pounds per acre of nitrogen per year and 44 pounds per acre of phosphorus. For the irrigated horticultural acres, water was applied at a frequency and rate defined by an auto-irrigation routine.

Land application of biosolids from wastewater treatment facilities was not simulated. Manure nutrients from wildlife populations are not included in the model simulation.
A summary of the total amount of nitrogen and phosphorus applied to agricultural land in the model simulation, including nitrogen and phosphorus applied to cultivated cropland in the APEX modeling, is presented in table 41.[34]

Windborne sediment and nutrients

In areas of the country where wind erosion is a significant resource concern, as in the Missouri River Basin, windblown sediment can be an important source of instream loads. The wind eroded material is deposited on many different landscapes and land uses including: other agricultural fields, filter or buffer areas, ditches, roadways, flood plains, and even directly into rivers and streams. In most cases windblown sediment will consist of unconsolidated material, which is easily transported into rivers and streams with surface water runoff. Because windblown material usually consists of fine and very fine soil particles, the portion that originates from cropland is usually rich in nutrients.

There are no published estimates of the magnitude of instream loads that originate from windborne sediment. Recognizing, however, that this is an important source of sediment and sediment-bound nutrients in areas prone to wind erosion, a rough estimate was calculated and incorporated into the model simulation. Windblown sediment materials were estimated conservatively by increasing the waterborne sediment loads delivered to the outlet of each 8-digit HUC by 10 percent. Nutrients carried with these windblown sediments were assumed to be in the same proportion as in the other water-eroded materials. Sediment and sediment-bound nitrogen and phosphorus loads estimated using this approach are presented in table 42.[35]

Estimates of windborne sediment and sediment-bound nutrients were not made for land uses other than cultivated cropland.

[34] For information on how manure nutrients were calculated for use in HUMUS modeling, see "Manure Loadings Used to Simulate Pastureland and Hayland in CEAP HUMUS/SWAT Modeling," available at: http://www.nrcs.usda.gov/technical/nri/ceap.

[35] Wind erosion rates and the field-level losses of windborne nitrogen and phosphorus were also estimated for cropped acres using the APEX model, as presented in chapter 4. The loads added at the outlet of 8-digit HUCs represented, on average for the region, 12.6 percent of the wind erosion rate for cropped acres, 23.4 percent of the nitrogen lost with windborne sediment, and 16.3 percent of the phosphorus lost with windborne sediment.

Table 41. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Missouri River Basin

Subregion	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
			Cultivated cropland			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	75,876	3,114	78,990	13,035	1,293	75,876
Missouri-Musselshell-Fort Peck Lake (code 1004)	22,930	3,808	26,737	3,341	1,578	22,930
Milk River Basin (code 1005)	28,087	190	28,276	4,546	84	28,087
Missouri-Poplar River Basin (code 1006)	51,208	2,579	53,787	9,046	1,077	51,208
Upper Yellowstone River Basin (code 1007)	11,036	1,791	12,827	2,315	980	11,036
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	21,673	2,897	24,570	3,665	1,110	21,673
Lower Yellowstone River (code 1010)	14,974	1,514	16,488	2,862	637	14,974
Missouri-Little Missouri-Lake Sakakawea (code 1011)	60,546	1,761	62,307	8,548	732	60,546
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	210,625	14,954	225,579	32,146	6,182	210,625
Missouri-White River -Fort Randall Reservoir (code 1014)	68,860	6,183	75,043	11,978	2,137	68,860
Niobrara River Basin (code 1015)	43,738	3,437	47,176	6,274	1,427	43,738
James River Basin (code 1016)	208,730	14,692	223,422	47,712	5,486	208,730
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	176,060	41,729	217,789	42,870	15,760	176,060
North Platte River Basin (code 1018)	28,170	6,133	34,303	3,887	2,324	28,170
South Platte River Basin (code 1019)	72,633	10,298	82,931	8,016	3,807	72,633
Middle and Lower Platte River Basin (code 1020)	126,586	9,491	136,077	24,317	4,245	126,586
Loup River Basin (code 1021)	71,063	14,766	85,829	12,867	5,541	71,063
Elkhorn River Basin (code 1022)	87,162	17,405	104,567	20,955	6,831	87,162
Missouri-Little Sioux River Basin (code 1023)	158,822	22,369	181,192	41,535	8,747	158,822
Missouri-Nishnabotna River Basin (code 1024)	172,546	11,310	183,856	46,506	4,258	172,546
Republican River Basin (code 1025)	249,762	23,405	273,167	37,718	8,768	249,762
Smoky Hill River Basin (code 1026)	181,915	7,054	188,968	25,435	3,265	181,915
Kansas-Big Blue River Basin (code 1027)	199,945	6,734	206,679	42,294	2,674	199,945
Chariton-Grand River Basin (code 1028)	53,489	4,420	57,908	18,000	1,685	53,489
Gasconade-Osage River Basin (code 1029)	44,053	306	44,359	13,539	97	44,053
Lower Missouri-Lower Missouri-Blackwater (code 1030)	59,114	4,166	63,280	16,897	1,441	59,114
Total	2,499,603	236,504	2,736,107	500,304	92,165	2,499,603
			Hayland			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	5,466	165	5,632	1,019	82	1,100
Missouri-Musselshell-Fort Peck Lake (code 1004)	867	19	886	441	11	452
Milk River Basin (code 1005)	1,056	12	1,068	140	7	147
Missouri-Poplar River Basin (code 1006)	0	0	0	19	0	19
Upper Yellowstone River Basin (code 1007)	1,440	18	1,458	695	9	704
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	1,609	64	1,674	921	39	960
Lower Yellowstone River (code 1010)	842	9	851	96	5	102
Missouri-Little Missouri-Lake Sakakawea (code 1011)	291	8	299	262	5	267
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	21,528	360	21,887	2,838	184	3,021
Missouri-White River -Fort Randall Reservoir (code 1014)	4,072	102	4,174	1,188	54	1,242
Niobrara River Basin (code 1015)	1,585	17	1,602	36	7	43
James River Basin (code 1016)	15,695	255	15,950	3,456	117	3,573
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	5,183	341	5,524	2,590	154	2,744
North Platte River Basin (code 1018)	5,380	127	5,507	564	45	608
South Platte River Basin (code 1019)	1,095	233	1,328	469	93	562
Middle and Lower Platte River Basin (code 1020)	647	39	687	127	13	140
Loup River Basin (code 1021)	467	11	477	70	4	74
Elkhorn River Basin (code 1022)	1,896	35	1,931	32	13	45
Missouri-Little Sioux River Basin (code 1023)	0	142	142	471	54	525
Missouri-Nishnabotna River Basin (code 1024)	6,528	136	6,665	945	68	1,014

Table 41--continued. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Missouri River Basin

Subregion	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
			Hayland continued—			
Republican River Basin (code 1025)	0	14	14	114	5	119
Smoky Hill River Basin (code 1026)	0	8	8	116	3	118
Kansas-Big Blue River Basin (code 1027)	11,545	137	11,682	243	58	300
Chariton-Grand River Basin (code 1028)	18,315	641	18,956	860	362	1,222
Gasconade-Osage River Basin (code 1029)	48,357	2,580	50,936	393	1,276	1,669
Lower Missouri-Lower Missouri-Blackwater (code 1030)	18,987	637	19,624	235	327	561
Total	172,853	6,110	178,964	18,340	2,993	21,333
			Pastureland and rangeland			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	6,102	24,421	30,523	3,714	14,861	18,574
Missouri-Musselshell-Fort Peck Lake (code 1004)	3,714	14,856	18,571	2,286	9,145	11,431
Milk River Basin (code 1005)	2,447	9,786	12,233	1,525	6,099	7,624
Missouri-Poplar River Basin (code 1006)	1,512	6,048	7,560	941	3,763	4,703
Upper Yellowstone River Basin (code 1007)	2,753	11,013	13,766	1,640	6,560	8,200
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	6,398	25,597	31,995	3,854	15,416	19,269
Lower Yellowstone River (code 1010)	3,034	12,136	15,170	1,890	7,559	9,448
Missouri-Little Missouri-Lake Sakakawea (code 1011)	3,667	14,666	18,333	2,269	9,077	11,347
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	18,798	75,195	93,992	11,461	45,845	57,306
Missouri-White River -Fort Randall Reservoir (code 1014)	7,831	31,337	39,169	4,741	18,968	23,709
Niobrara River Basin (code 1015)	6,568	26,274	32,842	3,950	15,799	19,749
James River Basin (code 1016)	9,974	40,162	50,136	5,791	23,260	29,051
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	6,509	26,052	32,561	3,094	12,381	15,475
North Platte River Basin (code 1018)	7,244	28,977	36,222	4,049	16,196	20,245
South Platte River Basin (code 1019)	7,963	31,851	39,814	3,383	13,530	16,913
Middle and Lower Platte River Basin (code 1020)	4,839	19,354	24,193	2,286	9,144	11,430
Loup River Basin (code 1021)	9,662	38,648	48,310	5,509	22,038	27,547
Elkhorn River Basin (code 1022)	5,695	22,782	28,477	2,559	10,236	12,795
Missouri-Little Sioux River Basin (code 1023)	4,221	16,902	21,123	1,712	6,855	8,567
Missouri-Nishnabotna River Basin (code 1024)	5,682	22,821	28,503	3,139	12,592	15,731
Republican River Basin (code 1025)	10,382	41,527	51,909	5,337	21,347	26,684
Smoky Hill River Basin (code 1026)	8,038	32,151	40,189	4,407	17,628	22,035
Kansas-Big Blue River Basin (code 1027)	7,477	29,954	37,431	3,993	15,987	19,980
Chariton-Grand River Basin (code 1028)	6,754	27,234	33,988	3,944	15,877	19,821
Gasconade-Osage River Basin (code 1029)	11,326	45,914	57,240	6,734	27,235	33,969
Lower Missouri-Lower Missouri-Blackwater (code 1030)	5,125	20,792	25,916	3,010	12,185	15,195
Total	173,715	696,450	870,165	97,216	389,582	486,798
			Horticulture			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	0	0	0	0	0	0
Missouri-Musselshell-Fort Peck Lake (code 1004)	2	0	2	1	0	1
Milk River Basin (code 1005)	0	0	0	0	0	0
Missouri-Poplar River Basin (code 1006)	0	0	0	0	0	0
Upper Yellowstone River Basin (code 1007)	0	0	0	0	0	0
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	0	0	0	0	0	0
Lower Yellowstone River (code 1010)	0	0	0	0	0	0
Missouri-Little Missouri-Lake Sakakawea (code 1011)	1	0	1	1	0	1
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	3	0	3	2	0	2
Missouri-White River -Fort Randall Reservoir (code 1014)	4	0	4	2	0	2
Niobrara River Basin (code 1015)	2	0	2	1	0	1
James River Basin (code 1016)	6	0	6	2	0	2

Table 41--continued. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Missouri River Basin

Subregion	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
			Horticulture continued—			
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	38	0	38	17	0	17
North Platte River Basin (code 1018)	25	0	25	11	0	11
South Platte River Basin (code 1019)	454	0	454	200	0	200
Middle and Lower Platte River Basin (code 1020)	132	0	132	58	0	58
Loup River Basin (code 1021)	4	0	4	2	0	2
Elkhorn River Basin (code 1022)	56	0	56	25	0	25
Missouri-Little Sioux River Basin (code 1023)	124	0	124	55	0	55
Missouri-Nishnabotna River Basin (code 1024)	102	0	102	45	0	45
Republican River Basin (code 1025)	10	0	10	5	0	5
Smoky Hill River Basin (code 1026)	7	0	7	3	0	3
Kansas-Big Blue River Basin (code 1027)	164	0	164	72	0	72
Chariton-Grand River Basin (code 1028)	84	0	84	37	0	37
Gasconade-Osage River Basin (code 1029)	750	0	750	330	0	330
Lower Missouri-Lower Missouri-Blackwater (code 1030)	486	0	486	214	0	214
Total	2,455	0	2,455	1,081	0	1,081
			Total for all agricultural land			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	87,444	27,700	115,144	17,768	16,235	34,003
Missouri-Musselshell-Fort Peck Lake (code 1004)	27,513	18,683	46,195	6,069	10,733	16,802
Milk River Basin (code 1005)	31,589	9,988	41,578	6,211	6,190	12,401
Missouri-Poplar River Basin (code 1006)	52,720	8,627	61,347	10,006	4,839	14,845
Upper Yellowstone River Basin (code 1007)	15,229	12,822	28,051	4,650	7,550	12,199
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	29,681	28,558	58,238	8,439	16,565	25,005
Lower Yellowstone River (code 1010)	18,850	13,658	32,509	4,848	8,201	13,049
Missouri-Little Missouri-Lake Sakakawea (code 1011)	64,505	16,435	80,940	11,080	9,814	20,894
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	250,954	90,508	341,461	46,446	52,211	98,656
Missouri-White River -Fort Randall Reservoir (code 1014)	80,767	37,622	118,389	17,908	21,158	39,066
Niobrara River Basin (code 1015)	51,893	29,728	81,622	10,261	17,233	27,494
James River Basin (code 1016)	234,405	55,108	289,513	56,962	28,863	85,824
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	187,790	68,122	255,913	48,571	28,296	76,867
North Platte River Basin (code 1018)	40,819	35,238	76,057	8,511	18,565	27,075
South Platte River Basin (code 1019)	82,144	42,383	124,527	12,067	17,430	29,498
Middle and Lower Platte River Basin (code 1020)	132,204	28,884	161,088	26,788	13,402	40,190
Loup River Basin (code 1021)	81,196	53,425	134,621	18,449	27,582	46,031
Elkhorn River Basin (code 1022)	94,810	40,221	135,031	23,571	17,081	40,651
Missouri-Little Sioux River Basin (code 1023)	163,168	39,413	202,581	43,773	15,656	59,429
Missouri-Nishnabotna River Basin (code 1024)	184,858	34,267	219,125	50,635	16,919	67,554
Republican River Basin (code 1025)	260,155	64,946	325,101	43,174	30,120	73,293
Smoky Hill River Basin (code 1026)	189,959	39,212	229,171	29,961	20,896	50,856
Kansas-Big Blue River Basin (code 1027)	219,132	36,824	255,956	46,602	18,719	65,321
Chariton-Grand River Basin (code 1028)	78,642	32,295	110,937	22,841	17,924	40,764
Gasconade-Osage River Basin (code 1029)	104,487	48,800	153,286	20,997	28,608	49,605
Lower Missouri-Lower Missouri-Blackwater (code 1030)	83,711	25,595	109,306	20,356	13,953	34,308
Total	2,848,626	939,065	3,787,690	616,941	484,740	1,101,680

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

Table 42. Summary of windborne sediment and nutrients included as loadings to rivers and streams in the HUMUS/SWAT model simulations,* Missouri River Basin

Subregion	Sediment (tons/year)	Nitrogen (tons/year)	Phosphorus (tons/year)
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	659,156	2,750	394
Missouri-Musselshell-Fort Peck Lake (code 1004)	264,333	1,252	210
Milk River Basin (code 1005)	434,066	1,976	215
Missouri-Poplar River Basin (code 1006)	769,123	3,010	333
Upper Yellowstone River Basin (code 1007)	255,048	701	115
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	160,999	410	63
Lower Yellowstone River (code 1010)	412,669	813	128
Missouri-Little Missouri-Lake Sakakawea (code 1011)	606,716	2,817	289
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	1,261,563	6,458	753
Missouri-White River -Fort Randall Reservoir (code 1014)	670,877	4,063	392
Niobrara River Basin (code 1015)	164,153	575	89
James River Basin (code 1016)	985,646	6,424	718
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	886,384	5,300	731
North Platte River Basin (code 1018)	417,014	1,353	191
South Platte River Basin (code 1019)	320,496	987	130
Middle and Lower Platte River Basin (code 1020)	348,735	1,668	208
Loup River Basin (code 1021)	158,085	822	85
Elkhorn River Basin (code 1022)	196,493	969	144
Missouri-Little Sioux River Basin (code 1023)	444,852	2,564	312
Missouri-Nishnabotna River Basin (code 1024)	157,338	801	107
Republican River Basin (code 1025)	646,405	3,535	484
Smoky Hill River Basin (code 1026)	1,175,359	5,074	672
Kansas-Big Blue River Basin (code 1027)	277,329	1,465	186
Chariton-Grand River Basin (code 1028)	63,955	286	41
Gasconade-Osage River Basin (code 1029)	60,010	264	43
Lower Missouri-Lower Missouri-Blackwater (code 1030)	28,728	131	17
Total	11,825,533	56,470	7,048

* Windborne loadings were introduced as sources at the 8-digit HUC outlets.

“Legacy Phosphorus” Not Accounted for in Modeling

“Legacy phosphorus” from cultivated cropland sources results from the over-application of phosphorus on farm fields in past years. When excessive amounts of fertilizer or manure are applied to a farm field, soil phosphorus levels increase dramatically. It may take decades for phosphorus levels to return to background levels once these practices are halted. Use of soil testing to determine the need for phosphorus applications can prevent further over-application, but there remains legacy phosphorus locked into the soil profile within the field, along the edge of the field and drainageways, and in streambeds that cannot be offset by current management activities. Legacy phosphorus can also come from sediment sources other than cultivated cropland.

The transport of sediment—and the phosphorus bound to those particles—from farm fields to rivers and streams can take many years. Eroded soil particles leaving a farm field can be deposited where runoff slows or ponding occurs before reaching a stream or river. Once the sediment has entered streams, some of the soil particles settle out and can remain in the streambed or settle on the floodplain when the water is high and slow moving. These sediments remain in place until a storm creates enough surface water runoff to re-suspend the previously eroded soil, or until streamflow cuts into streambanks made up of deposits of previously eroded soil. Windborne sediment transported into waterways can similarly be a mixture of newly eroded and previously eroded materials.

Consequently, measured phosphorus levels in rivers and streams include not only phosphorus lost from farm fields as a result of current farming activities but also “legacy phosphorus” from prior farming activities as well as prior deposits from non-farming sources. Some of this sediment-adsorbed “legacy phosphorus” can be solubilized by chemical reactions within the water body and measured as soluble phosphorus.

The simulation models used in this study do not account for these “legacy phosphorus” levels. There is recognition, however, that “legacy phosphorus” can be an important contributor to current levels of instream phosphorus loads, including soluble phosphorus loads.

Urban Sources

Urban sources include (1) loads from point sources discharged from industrial and municipal wastewater treatment plants and (2) loads from urban land runoff.

Discharges from industrial and municipal wastewater treatment plants can be major sources of nutrients and sediment in some watersheds. Point sources of water flow, total suspended sediment, total phosphorus, and Kjeldahl nitrogen were estimated using county-level data on population change to adjust 1980 estimates of point source loadings published by Resources for the Future (Gianessi and Peskin 1984) to the year 2000. The original Resources for the Future assessment covered 32,000 facilities, including industries, municipal wastewater treatment plants, and small sanitary waste facilities for the years 1977 to 1981. A GIS-based procedure was used to convert county data to the 8-digit HUC level. Point source loads are aggregated within each watershed and average annual loads input into SWAT at the watershed outlet.

Urban runoff is estimated separately for three categories of cover within an urban HRU: 1) Pervious surfaces such as lawns, golf courses, and gardens, 2) impervious surfaces hydraulically connected to drainage systems such as paved roads and paved streets draining to storm drains, and 3) impervious surfaces not hydraulically connected to drainage systems such as a house roof draining to a pervious yard that is not directly connected to drains (composite urban surface consisting of impervious roof surface and pervious yard surface).

Pervious surfaces are simulated in the same manner as other grass areas (such as pasture). Surface runoff from pervious surfaces is calculated using the NRCS Runoff Curve Number (RCN). (The RCN is an empirical parameter used in surface hydrology for predicting direct runoff or infiltration.) Nitrogen fertilizer (40 pounds per acre per year) is applied on grassed urban areas such as lawns and grassed roadsides using an auto-fertilizer routine to grow grass without undue nitrogen stress. The grass is considered irrigated as needed based on plant stress demand using an auto-irrigation routine.

For estimating surface water runoff from impervious urban areas, a runoff curve number of 98 was used for surfaces connected hydraulically to drainage systems. A composite runoff curve number was used for impervious surfaces not hydraulically connected to drainage systems. Sediment and nutrients carried with stormwater runoff to streams and rivers were estimated using the build up-wash off algorithm developed by Huber and Dickinson (1988).

The concept behind the build up-wash off algorithm is that over a period of time, dust, dirt, and other constituents are built up on street surfaces during dry periods. During a storm event the materials are washed off. The algorithms were developed from an EPA national urban water quality database that relates storm runoff loads to rainfall, drainage area, and impervious area.

Sediment produced from construction sites was also simulated in SWAT. Construction areas were assumed to represent 3 percent of urban areas. Parameters in the soil input file were modified to produce surface runoff and sediment yield that mimicked the average sediment load from published studies on construction sites.

A summary of the total amount of nitrogen and phosphorus applied to non-agricultural land in the model simulation is presented in table 43. Nutrients from septic systems were not included in the model simulations as data on locations of septic systems, populations using the septic systems, and types of septic systems were not available.

Atmospheric nitrogen deposition

Atmospheric deposition of nitrogen can be a significant component of the nitrogen balance. Nitrogen deposition data (loads and concentrations) were developed from the National Atmospheric Deposition Program/National Trends Network database (NADP 2004). When a rainfall event occurs in the model simulation, the amount of rainfall is multiplied by the average ammonium and nitrate concentrations calculated for the watershed to account for wet deposition. An additional amount of ammonium and nitrate are added on a daily basis to account for dry deposition. A summary of the total amount of nitrogen deposition included as inputs to the HUMUS/SWAT model simulation is presented in table 43.

Table 43. Summary of nutrients applied to urban land, nutrients originating from point sources, and wet and dry atmospheric deposition of nitrogen used as inputs to the HUMUS/SWAT model, Missouri River Basin.

	Urban land	Point sources		Wet and dry atmospheric deposition
Subregion	Nitrogen fertilizer (tons/year)	Nitrogen (tons/year)	Phosphorus (tons/year)	Nitrogen (tons/year)
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	3,636	1,181	293	18,393
Missouri-Musselshell-Fort Peck Lake (code 1004)	864	524	133	12,896
Milk River Basin (code 1005)	1,153	545	90	5,702
Missouri-Poplar River Basin (code 1006)	1,981	131	33	3,405
Upper Yellowstone River Basin (code 1007)	1,141	1,473	388	11,102
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	1,869	3,005	768	28,165
Lower Yellowstone River (code 1010)	1,099	105	27	8,672
Missouri-Little Missouri-Lake Sakakawea (code 1011)	2,160	104	26	10,698
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	7,563	1,814	398	53,607
Missouri-White River -Fort Randall Reservoir (code 1014)	2,739	137	35	22,790
Niobrara River Basin (code 1015)	1,807	91	24	18,205
James River Basin (code 1016)	5,400	310	77	16,692
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	4,877	250	64	9,737
North Platte River Basin (code 1018)	2,450	1,550	449	30,413
South Platte River Basin (code 1019)	8,690	11,834	3,418	22,677
Middle and Lower Platte River Basin (code 1020)	2,965	972	246	7,716
Loup River Basin (code 1021)	1,960	178	43	23,006
Elkhorn River Basin (code 1022)	1,810	447	110	6,255
Missouri-Little Sioux River Basin (code 1023)	4,914	2,905	683	5,240
Missouri-Nishnabotna River Basin (code 1024)	5,539	1,575	397	13,328
Republican River Basin (code 1025)	5,381	561	153	17,974
Smoky Hill River Basin (code 1026)	4,998	430	118	17,603
Kansas-Big Blue River Basin (code 1027)	6,116	1,229	314	18,960
Chariton-Grand River Basin (code 1028)	3,260	160	41	19,057
Gasconade-Osage River Basin (code 1029)	6,298	1,596	393	47,711
Lower Missouri-Lower Missouri-Blackwater (code 1030)	6,553	1,467	372	20,620
Total	97,224	34,571	9,093	470,624

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

Routing and channel processes

SWAT simulates stream/channel processes including channel flood routing, channel sediment routing, nutrient and pesticide routing, and transformations modified from the QUAL2E model (fig. 90).

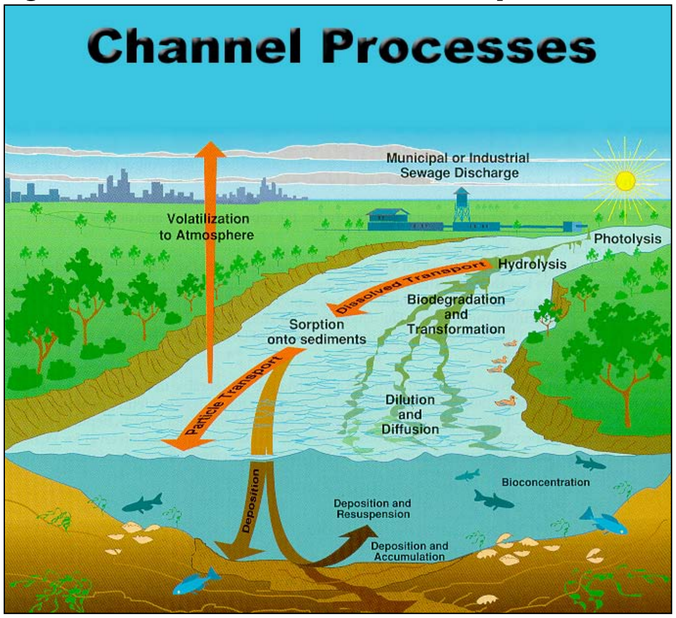
- **Flood routing**. As water flows downstream, some may be lost due to evaporation and transmission through the channel bed. Another potential loss is removal of water from the channel for agricultural or human use. Flow may be supplemented by rainfall directly on the channel and/or addition of water from point source discharges.

- **Sediment routing—deposition, bed degradation, and streambank erosion**. Sediment transport in the stream network is a function of two processes, deposition and degradation. SWAT computes deposition and degradation simultaneously within the reach. Deposition is based on the fall velocity of the sediment particles and the travel time through each stream. Stream power is used to predict bed and bank degradation; excess stream power results in degradation. Bed degradation and streambank erosion are based on the erodibility and vegetative cover of the bed or bank and the energy available to carry sediment (a function of depth, velocity, and slope). The maximum amount of sediment that can be transported from a reach segment is a function of the peak channel velocity. Available stream power is used to re-entrain loose and deposited material until all of the material is removed.[36] Nearly half of the sediment load estimated for the Missouri River Basin comes from streambank erosion.

- **Nutrient routing**. Nutrient transformations in the stream are controlled by the instream water quality component of the model. The model tracks nutrients dissolved in the stream and nutrients adsorbed to the sediment. Dissolved nutrients are transported with the water, while those adsorbed to sediments are deposited with the sediment on the bed of the channel.

- **Pesticide routing**. As with nutrients, the total pesticide load in the channel is partitioned into dissolved and sediment-attached components. While the dissolved pesticide is transported with water, the pesticide attached to sediment is affected by sediment transport and deposition processes. Pesticide transformations in the dissolved and adsorbed phases are governed by first-order decay relationships. The major instream processes simulated by the model are settling, burial, resuspension, volatilization, diffusion, and transformation.

Figure 90. SWAT model channel simulation processes



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[36] There are no national estimates of streambank erosion that can be uniformly used to calibrate this component of the model. Parameters governing instream sediment processes are adjusted in concert with those governing upland sediment yields such that HUMUS predictions at calibration sites mimic measured sediment data. Sediment data collected at a single stream gauging site is a combination of upland and instream sources, which cannot be proportioned by source. Collectively a network of sediment monitoring sites may be used to develop a sediment budget for a watershed which may include a stream bank component. When such studies are available for a HUMUS region they are used as ancillary data during model calibration.

Reservoirs

Reservoirs alter the dynamics of a free-flowing river, resulting in different rates of sediment deposition and chemical transformations. SWAT includes routines for reservoirs that account for the hydrological aspects of reservoirs. Basic reservoir data such as storage capacity and surface area were obtained from the dams database.

- **Reservoir outflow**. A simple target volume approach was used in this study to simulate reservoir outflow. The algorithm attempts to keep reservoir storage near the principal spillway volume during the flood season but allow water storage to accumulate above the principal storage during the non-flood season.

- **Sediment routing**. The concentration of sediment in the reservoir is estimated using a simple continuity equation based on volume and concentration of inflow, outflow, and water retained in the reservoir. Settling of sediment in the reservoir is governed by an equilibrium sediment concentration and the median sediment particle size. The amount of sediment in the reservoir outflow is the product of the volume of water flowing out of the reservoir and the suspended sediment concentration in the reservoir at the time of release.

- **Reservoir nutrients**. The model assumes that (1) the reservoir is completely mixed, (2) phosphorus is the limiting nutrient, and (3) total phosphorus is a measure of the trophic status. The phosphorus mass balance equation includes the concentration in the reservoir, inflow, outflow, and overall loss rate.

- **Reservoir pesticides**. The model partitions the system into a well-mixed surface water layer underlain by a well-mixed sediment layer for simulating the fate of pesticides. The pesticide is partitioned into dissolved and particulate phases in both the water and sediment layers. The major processes simulated by the model are loading, outflow, transformation, volatilization, settling, diffusion, resuspension, and burial.

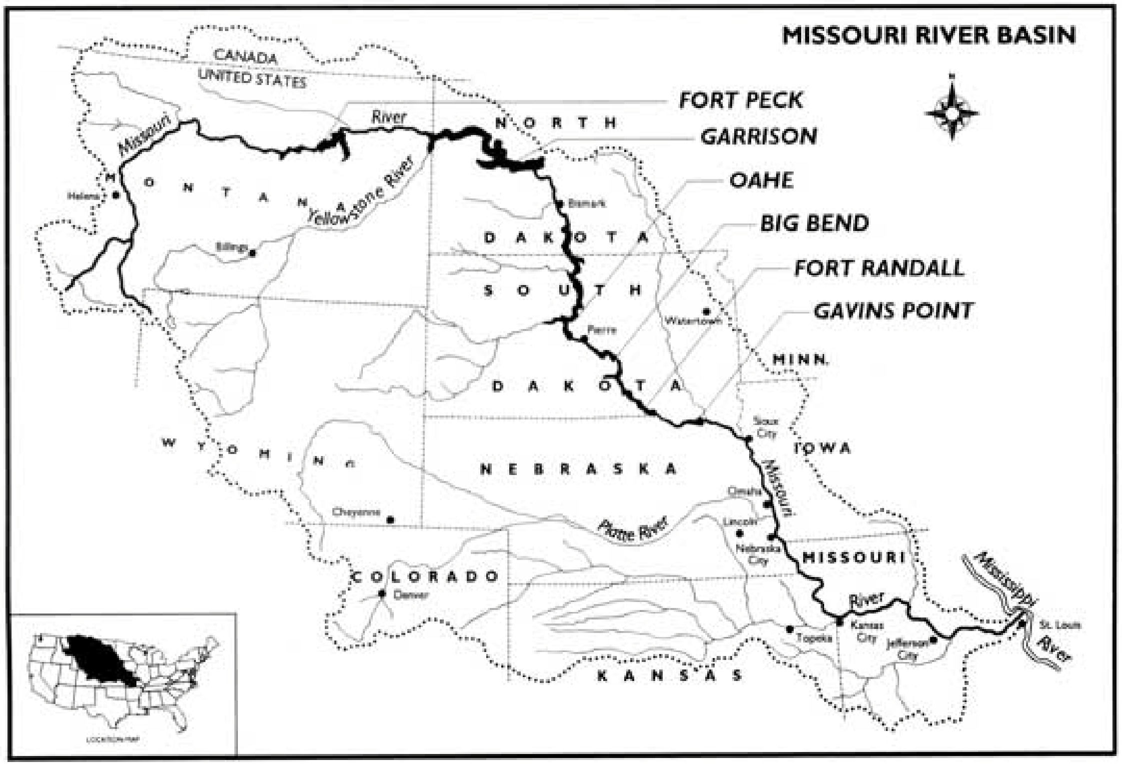
Major reservoirs or lakes are located near the outlets of subregions 1004 (Fort Peck Reservoir), 1011 (Garrison Reservoir), 1013 (Lake Oahe and Big Bend Reservoir), 1014 (Fort Randal Reservoir) and 1017 (Gavins Point Reservoir) on the main stem of the Missouri River (fig. 91). These reservoirs trap and retain significant amounts of sediment, nutrients, and pesticides.

Without the reservoirs, the Missouri River would have transported sediment loads averaging 25 million tons per year in the vicinity of Fort Peck, Montana; 150 million tons per year at Yankton, South Dakota; 175 million tons per year at Omaha, Nebraska; and approximately 250 million tons per year at Hermann, Missouri (near its confluence with the Mississippi River). Reservoirs trap a major portion of this sediment. Approximately 90,000 acre-feet of sediment are trapped in four major mainstem reservoirs of the Missouri River (Fort Peck, Garrison, Oahe, and Fort Randall).

In addition to sediment transported to the reservoirs by the Missouri River and its tributaries, some sediment enters the system through shoreline erosion processes within lakes and reservoirs. Lake shoreline material consists of highly erodible soils that are subjected to the action of waves and ice. The shorelines of Missouri River reservoirs stretch thousands of miles, most of which are not protected (US Army Corps of Engineers 2006).

Downstream from the Gavin’s Point Dam, the Missouri River is nearly sediment free. As it flows, however, it derives new loads of sediment from its bed, banks, and tributaries. Sediment observations made at many locations in the river basin show this trend. In the model setup, the parameters controlling sediment deposition in reservoirs were adjusted to mimic this observed trend.

Figure 91. Major reservoirs and lakes along the mainstem of the Missouri River



Calibration

Delivery of surface water and subsurface water from upland processes (HRUs and CEAP sample points) was spatially calibrated for each subregion to ensure that streamflow was in agreement with long-term average runoff for the region. Hydrologic parameters in APEX (cultivated cropland) and SWAT (other HRUs) were adjusted separately for each 8-digit watershed until differences in the long-term water yield were minimized. Time series of predicted annual and monthly streamflow were compared against the monitored counterpart. If necessary, the channel losses, seepage, and evaporation losses in reservoirs were adjusted to match the predicted flow time series with that of observed data. The calibration period is from 1961–1990 and the validation period from 1991–2006. Most of the flow calibration was carried out for the upland runoff with minimal or no parameterization for the time series of annual and monthly streamflow. [37]

For sediment calibration, observations were taken from USGS monitoring stations. Most of the sediment observations were grab-sample concentrations of suspended sediment. These, along with monitored daily flow data, were processed using a load estimator or load runner program to estimate annual average sediment load. The estimated annual average sediment load was used to validate the predicted sediment load from HUMUS. In the Missouri River Basin, predicted sediment load was calibrated/validated to match the observations collected at six different gauging stations. For calibration of upland soil erosion, the soil erodibility factor and residue cover were adjusted.

For adjusting instream sediment load, parameters controlling stream power and sediment carrying capacity of the channel were adjusted. Delivery ratios from field to 8-digit watershed and 8-digit watershed to river were adjusted to match predicted sediment load with that of observations for each validation station. Where necessary, parameters affecting settling of sediment in reservoirs were also adjusted.

Eight gauging stations were selected in the Missouri River Basin for nutrient calibration. Most of the data for nutrient calibration were taken from the USGS-NASQAN data monitoring program. Nutrient observations were available for five gauging stations for the Missouri River and three stations for its tributaries (Yellowstone, Platte, and Osage Rivers). Nutrient loads were estimated from grab-sample concentrations using the same procedure outlined for sediment.

For calibration of upland nutrient load, parameters controlling nutrient uptake by plants, leaching to groundwater, and mineralization were adjusted. For calibration of instream nutrient load, parameters affecting benthic source rate, mineralization, hydrolysis, and settling with sediment were adjusted. Where necessary, parameters affecting settling of nutrients in reservoirs were also adjusted.

Data were not available for calibration of atrazine loads.

[37] For a complete documentation of calibration procedures and results for the Missouri River Basin, see “Calibration and Validation of CEAP HUMUS” at http://www.nrcs.usda.gov/technical/nri/ceap.

The “background” scenario

An additional scenario was conducted to represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by simulating with APEX a grass-and-tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.[38] All SWAT modeling remained the same for this scenario. Thus, “background” loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Source Loads and Instream Loads

All source loads are introduced into SWAT at the outlet of each watershed (8-digit hydrologic unit code [HUC]). Flows and source loads from upstream watersheds are routed through each downstream watershed, including reservoirs when present.[39]

A sediment delivery ratio was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The sediment delivery ratio used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU.[40]

In addition to the sediment delivery ratio, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment-attached pesticide concentrations transported with sediment to the watershed outlet divided by their concentrations at the edge of the field. As sediment is transported from the edge of field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

There are four points in the modeling process at which source loads or instream loads are assessed, shown in the schematic in figure 92 for sediment.

1. Edge-of-field loads from cultivated cropland—aggregated APEX model output as reported in the previous chapter.

2. Delivery to the watershed outlet from cultivated cropland—aggregated edge-of-field loads after application of delivery ratios. Loadings delivered to streams and rivers differ from the amount leaving the field because of losses during transport from the field to the stream. Delivery ratios are used to make this adjustment.

3. Delivery to the watershed outlet from land uses other than cultivated cropland as simulated by SWAT, after application of delivery ratios. Point sources are included.

4. Loadings in the stream or river at a given point. Instream loads include loadings delivered to the watershed outlet from all sources as well as loads delivered from upstream watersheds, after accounting for channel and reservoir processes.

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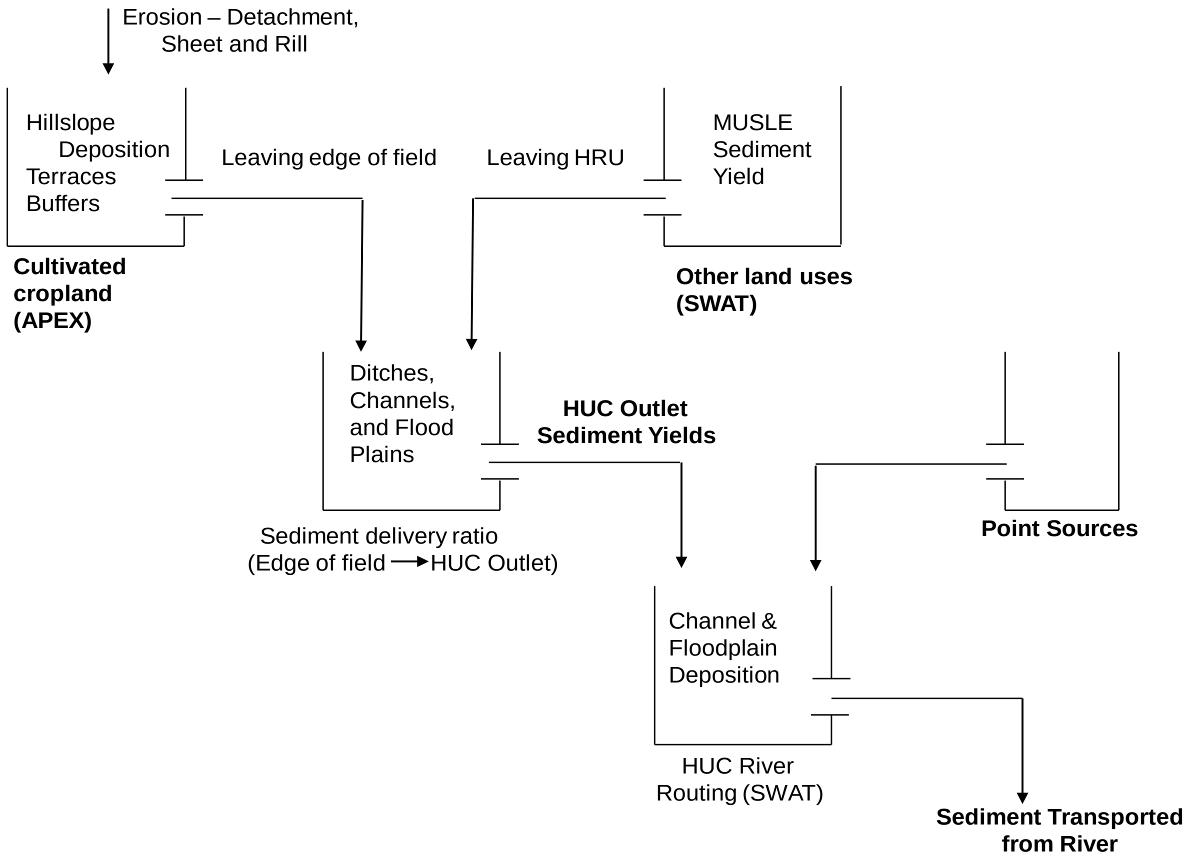
[38] In a natural ecosystem, the vegetative cover would include a mix of species, which would continually change until a stable ecosystem was established. APEX allows for multiple species and simulates plant competition over time according to plant growth, canopy cover, vegetative form, and relative maturity or growth stage. The initial mix of species at the beginning of the 47-year simulation was similar to the mix of grasses and trees used to establish long-term conserving cover. Mixes included at least one grass and one legume. Over the 47-year simulation, the mix of grasses and trees shifted due to plant competition. The grass species typically dominate in the simulation until shaded out by tree cover. For further details on how the background simulation was conducted, see “Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for the CEAP National Cropland Assessment” at http://www.nrcs.usda.gov/technical/nri/ceap.

[39] For a complete documentation of HUMUS/SWAT as it was used in this study, see “The HUMUS/SWAT National Water Quality Modeling System and Databases” at http://www.nrcs.usda.gov/technical/nri/ceap.

[40] For a complete documentation of delivery ratios used for the Missouri River Basin, see “Delivery Ratios Used in CEAP Cropland Modeling” at http://www.nrcs.usda.gov/technical/nri/ceap.

Figure 92. Schematic of sediment sources and delivery as modeled with HUMUS/SWAT for the Ohio-Tennessee River Basin



Modeling Land Use in the Missouri River Basin

The USGS National Land-Cover Database for 2001 (Homer et al. 2007) was the principal source of acreage estimates for HUMUS/SWAT modeling. The 2003 National Resources Inventory (USDA/NRCS 2007) was used to adjust NLCD cropland acreage estimates to include acres in Conservation Reserve Program (CRP) General Signups, used here to represent cropland in long-term conserving cover. Consequently, cultivated cropland acres used to simulate the water quality effects of conservation practices differ slightly from the cropped acres reported in the previous chapters, which were estimated on the basis of the CEAP Cropland sample.

Estimates of the acreage by land use, exclusive of water, used in the model simulation to estimate the effects of conservation practices in this chapter are presented in figure 93 and table 44. Rangeland and pastureland make up slightly more than half of the acres in the basin. Cultivated cropland is the second largest share of land use, including almost 30 percent of the land in the basin. Forest and other land uses make up about 11 percent. Urban land and hayland are minor land uses in this region.

Cultivated cropland acres are distributed throughout the region (tables 4 and 44). The Republican River Basin (code 1025) has the most acres of cultivated cropland—9.4 percent of the cultivated cropland in the region. The next three subregions with the most cultivated cropland are the Cheyenne River Basin (code 1013), the James River Basin (code 1016), and the Smoky Hill River Basin (code 1026). These four subregions contain almost one-third of the cultivated cropland acres in the region.

The concentration of cultivated cropland within each subregion is an important indicator of the extent to which sediment and nutrient loads in rivers and streams are influenced by farming operations. Cultivated cropland accounts for more than 50 percent of the land base in 10 of the 29 subregions. Cultivated cropland is most concentrated in subregion 1023 (Missouri-Little Sioux River Basin), where 78 percent of the area is cultivated cropland (table 4). About two thirds of two additional subregions is cultivated cropland—1017 (Missouri-Big Sioux-Lewis-Clark Lake) with 67 percent and 1024 (Missouri-Nishnabotna River Basin) with 65 percent.

Cultivated cropland is a minor land use in six subregions, where it accounts for 8 percent or less of the area within each subregion—1002 (Missouri headwaters), 1007 (Upper Yellowstone River Basin), 1008 (Big Horn River Basin), 1009 (Powder-Tongue River Basins), 1012 (Missouri-Grand-Moreau-Lake Oahe), and 1018 (North Platte River Basin) (table 4).

Figure 93. Percent acres for land use/cover types in the Missouri River Basin, exclusive of water

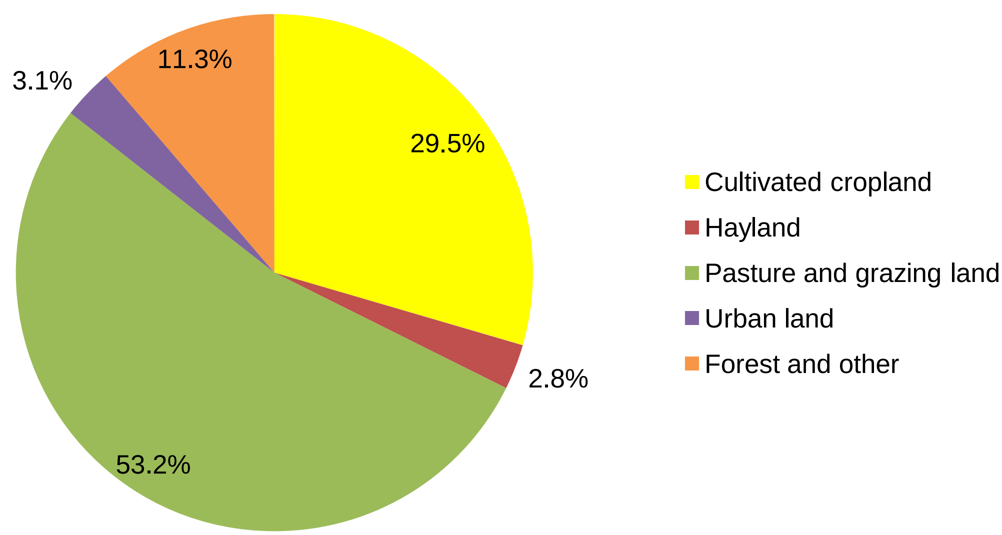


Table 44. Acres by land use, exclusive of water, used in model simulations to estimate instream sediment, nutrient, and atrazine loads for the Missouri River Basin

Subregions	Cultivated cropland (acres)*	Hay land not in rotation with crops (acres)	Pasture and grazing land not in rotation with crops (acres)**	Urban land (acres)	Forest and other (acres)***	Total land exclusive of water (acres)
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	4,333,244	371,659	10,584,521	368,019	5,892,400	21,549,843
Missouri-Musselshell-Fort Peck Lake (code 1004)	2,434,596	124,575	10,395,393	88,757	1,762,117	14,805,438
Milk River Basin (code 1005)	3,394,217	62,711	5,700,841	122,399	299,245	9,579,413
Missouri-Poplar River Basin (code 1006)	3,843,637	4,228	2,560,219	203,514	165,236	6,776,834
Upper Yellowstone River Basin (code 1007)	683,901	190,444	5,657,481	113,809	2,466,027	9,111,663
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	563,581	247,315	21,725,378	189,595	3,895,258	26,621,127
Lower Yellowstone River (code 1010)	1,187,451	45,222	6,836,797	113,115	698,216	8,880,801
Missouri-Little Missouri-Lake Sakakawea (code 1011)	3,349,305	79,720	6,119,984	227,726	725,152	10,501,887
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	7,635,140	1,269,461	25,798,922	797,453	2,900,432	38,401,408
Missouri-White River -Fort Randall Reservoir (code 1014)	2,777,598	394,518	8,462,679	287,292	822,150	12,744,238
Niobrara River Basin (code 1015)	1,301,916	54,202	6,895,434	184,389	483,356	8,919,296
James River Basin (code 1016)	7,274,251	1,207,245	3,704,396	558,097	483,867	13,227,856
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	6,063,109	727,083	1,180,719	510,896	349,603	8,831,410
North Platte River Basin (code 1018)	1,587,299	273,189	15,225,280	254,289	2,444,849	19,784,906
South Platte River Basin (code 1019)	4,306,970	135,373	7,345,822	890,970	2,615,154	15,294,290
Middle and Lower Platte River Basin (code 1020)	2,871,335	45,601	1,718,261	308,076	245,986	5,189,260
Loup River Basin (code 1021)	1,374,243	38,579	7,606,790	194,400	393,793	9,607,804
Elkhorn River Basin (code 1022)	2,643,130	59,495	1,386,809	189,488	181,421	4,460,343
Missouri-Little Sioux River Basin (code 1023)	4,675,112	103,755	417,530	505,213	227,486	5,929,096
Missouri-Nishnabotna River Basin (code 1024)	5,646,766	394,485	1,346,371	571,132	651,066	8,609,821
Republican River Basin (code 1025)	8,990,231	25,923	6,098,372	558,375	229,021	15,901,923
Smoky Hill River Basin (code 1026)	6,743,897	26,139	5,175,366	518,167	227,427	12,690,996
Kansas-Big Blue River Basin (code 1027)	4,985,834	384,644	2,899,672	623,160	710,921	9,604,231
Chariton-Grand River Basin (code 1028)	2,811,282	723,107	1,921,737	340,408	1,139,252	6,935,786
Gasconade-Osage River Basin (code 1029)	1,661,763	1,523,146	3,410,380	663,477	4,447,218	11,705,984
Lower Missouri-Lower Missouri-Blackwater (code 1030)	1,997,085	607,309	1,322,007	722,131	1,899,787	6,548,319
Regional total	95,136,893	9,119,126	171,497,166	10,104,349	36,356,440	322,213,974

*Acres of cultivated cropland include land in long-term conserving cover as well as hay land and pastureland in rotation with crops.
**Includes grass and brush rangeland categories.
***Includes forests (all types), wetlands, horticulture, and barren land.
Note: Estimates were obtained from HUMUS databases on land use, and thus cultivated cropland estimates do not exactly match the acreage estimates obtained from the NRI-CEAP sample.

Loads Delivered from Cultivated Cropland to Rivers and Streams

HUMUS/SWAT accounts for the transport of water, sediment, pesticides, and nutrients from the land to receiving streams and routes the flow downstream to the next watershed and ultimately to estuaries and oceans. Not all of the sediment, nutrients, and pesticides that leave farm fields is delivered to streams and rivers. Some material is bound up in various parts of the landscape during transport. Loads delivered from cultivated cropland and other sources to rivers and streams within the Missouri River Basin are presented in this section. Instream loads for all sources, which incorporate instream degradation processes and streambed deposition and accumulation of the sediment, nutrients, and pesticides *after* delivery to streams and rivers, are presented in the following section.

The water quality effects of conservation practices in use during 2003–06 on loads delivered from cultivated cropland to rivers and streams were assessed by comparing HUMUS/SWAT model simulation results for the baseline conservation condition to simulation results for the no-practice scenario. For the no-practice scenario, only the conditions for cultivated cropland were changed, as described previously. All other aspects of the simulations—including sediment and nutrient loads from point sources and land uses other than cultivated cropland—remained the same.

The field-level model results for the treatment scenarios with additional erosion control practices and nutrient management (chapter 6) were used with the HUMUS/SWAT model to determine the *potential for further reductions* in loads delivered from cultivated cropland to rivers and streams throughout the region with additional conservation treatment. Percent reductions relative to the baseline conservation condition were estimated for each of two treatment scenarios—

1. Treatment of the 1.1 million critical under-treated acres, which have a "high" need for additional treatment for one or more resource concerns (1.3 percent of cropped acres in the region), and
2. Treatment of all 15.3 million acres with a "high" or "moderate" need for additional treatment for one or more resource concerns (18.3 percent of cropped acres in the region).

Acres not receiving treatment in the simulation retained baseline values. Thus, the distribution of under-treated acres within the region influences the extent to which individual subregions benefit from additional treatment, since additional treatment was simulated only for the under-treated acres. The distribution of under-treated acres within the Missouri River Basin is shown in chapter 5, table 35.

*In summary, findings for the Missouri River Basin indicate that for the baseline conservation condition, sediment, nutrient, and atrazine loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, are—*

- *14.0 million tons of sediment (72 percent of loads from all sources);*
- *500 million pounds of nitrogen (68 percent of loads from all sources);*
- *33 million pounds of phosphorus (46 percent of loads from all sources); and*
- *90,000 pounds of atrazine.*

*Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced sediment, nutrient, and atrazine loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, by —*

- *76 percent for sediment;*
- *54 percent for nitrogen;*
- *60 percent for phosphorus, and*
- *36 percent for atrazine.*

*Model simulations further showed that if all of the under-treated acres (15.3 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads **delivered to rivers and streams from cultivated cropland sources** in the region would be reduced, relative to the baseline conservation condition, by—*

- *28 percent for sediment,*
- *13 percent for nitrogen,*
- *12 percent for phosphorus, and*
- *5 percent for atrazine.*

Sediment

Baseline condition. Model simulation results show that of the 21.8 million tons of sediment exported from farm fields in the Missouri River Basin (table 45), about 14.0 million tons are delivered to rivers and streams each year, on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 0.15 ton per cultivated cropland acre is delivered to rivers and streams per year, on average, for the region (table 45).

The subregion with the largest amount of sediment delivered to rivers and streams from cultivated cropland annually is the Missouri-Nishnabotna subregion (code 1024)—1.5 million tons per year. About 42 percent of the sediment delivered to rivers and streams from cultivated cropland originates in six subregions—

- the Missouri-Nishnabotna (code 1024), with 11 percent,
- the Kansas-Big Blue river Basin (code 1027), with 7 percent,
- the Lower Missouri River Basin (code 1030), with 6 percent,
- the Chariton-Grand River Basin (code 1028) ,with 6 percent,
- the Smoky Hill River Basin (code 1026), with 6 percent, and
- the Cheyenne and Missouri-Grand-Moreau-Lake Oahe River Basins (codes 1012 and 1013), with 6 percent.

On a per-acre basis, sediment delivery to rivers and streams exceeds 0.25 ton per cultivated cropland acre in five subregions, with the highest in the Lower Missouri River Basin—

- the Lower Missouri River Basin (code 1030), with 0.44 ton per acre,
- the Gasconade-Osage River Basin (code 1029), with 0.41 ton per acre,
- the Lower Yellowstone River Basin (code 1010), with 0.32 ton per acre,
- the Chariton-Grand River Basin (code 1028), with 0.30 ton per acre, and
- the Missouri-Nishnabotna (code 1024), with 0.27 ton per acre.

These annual average rates of sediment delivery to rivers and streams within the region are lower than rates in other areas of the country, primarily because of less precipitation. For example–

Region	Average annual precipitation (inches) for cultivated cropland acres	Average annual tons/acre/year of sediment delivered to rivers and streams from cultivated cropland
Missouri River Basin	23	0.15
Upper Mississippi River Basin	34	0.29
Ohio-Tennessee River Basin	42	0.60
Great Lakes Region	34	0.23
Chesapeake Bay Region	42	0.45

Sediment delivered to rivers and streams from cultivated cropland represents about 72 percent of the total sediment load delivered from all sources in the region (table 46, fig. 94). This percentage ranges, however, from a low of 9 percent in the Big Horn and Powder-Tongue River subregions (codes 1008 and 1009) to 90 percent or more in these six subregions—

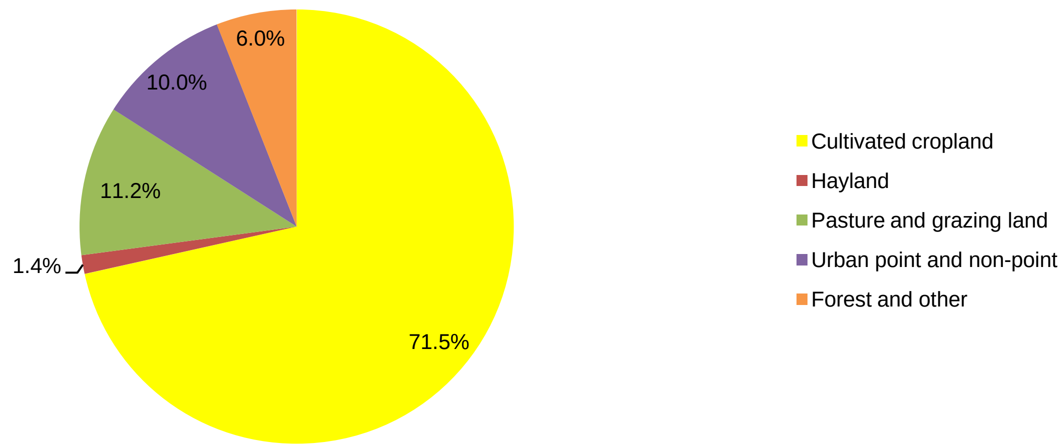
- the Missouri-Poplar River Basin (code 1006), with 95 percent,
- the James River Basin (code 1016), with 93 percent,
- the Republican River Basin (code 1025), with 92 percent,
- the Missouri-Little Missouri-Lake Sakakawea River Basin (code 1011), with 91 percent,
- the Milk River Basin (code 1005) and the Missouri-Big Sioux-Lewis-Clark River Basins (code 1017), each with 90 percent.

Pastureland and rangeland account for 11 percent of the sediment loads delivered to rivers and streams within the region (table 46, fig. 94). Pastureland and rangeland account for 27 to 50 percent of delivered sediment loads, however, in six subregions. Contributions from cultivated cropland are low in these six subregions (table 46).

Runoff from urban areas accounts for 10 percent of the sediment delivered to rivers and streams in this region (table 46, fig. 94). The two subregions nearest the confluence of the Missouri and the Mississippi Rivers (codes 1029 and 1030) have the highest sediment loads associated with urban runoff, accounting for 25 and 22 percent of the loads in those subregions, respectively.

Hayland, urban point sources, and forest and other land covers are minor contributors to sediment loads in most subregions.

Figure 94. Percentage by source of average annual sediment loads delivered to rivers and streams for the baseline conservation condition, Missouri River Basin



Effects of conservation practices. Sediment loads delivered to streams and rivers would have been much larger if soil erosion control practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of sediment from fields to rivers and streams by about 76 percent (table 47, fig. 95), on average. Reductions due to conservation practices range from a low of 51 percent for the Lower Yellowstone River Basin (code 1010) to a high of 89 percent for the South Platte River Basin (code 1019).

Potential gains from further conservation treatment. Because of the relatively low levels of water-eroded sediment loss from farm fields throughout most of this region, the potential for additional gains from further conservation treatment is limited, as shown in figure 77 in the previous chapter. Nevertheless, model simulations show that use of additional erosion control practices on the 15.3 million under-treated acres in the region would reduce overall sediment loads delivered to rivers and streams by about 4 million tons per year, representing a reduction from baseline levels of 28 percent (table 48, fig. 95).

The largest gain in terms of tons saved would occur in the Missouri-Nishnabotna River Basin, where 746,000 tons of sediment per year would be saved with additional conservation treatment, representing a 49-percent reduction from baseline levels (table 48).

In terms of percent reduction, four subregions would have sediment loads delivered to rivers and streams reduced by more than 50 percent—

- the Lower Yellowstone River Basin (code 1010), with a 78-percent reduction,
- the South Platte River Basin (code 1019), with a 71-percent reduction,
- the Big Horn and Powder-Tongue River Basins (codes 1008 and 1009), with a 62-percent reduction, and
- the Chariton-Grand River Basin (code 1028), with a 52-percent reduction.

Table 45. Average annual sediment loads at the ***edge of field*** (APEX model output) and ***delivered from cultivated cropland to rivers and streams*** for the baseline conservation condition, Missouri River Basin

	Edge-of-field loads		Delivered to rivers and streams		
Subregions	Amount (1,000 tons)	Tons per cultivated cropland acre	Amount (1,000 tons)*	Percent of regional total	Tons delivered per cultivated cropland acre
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	333	0.08	450	3	0.10
Missouri-Musselshell-Fort Peck Lake (code 1004)	119	0.05	208	1	0.09
Milk River Basin (code 1005)	136	0.04	361	3	0.11
Missouri-Poplar River Basin (code 1006)	184	0.05	454	3	0.12
Upper Yellowstone River Basin (code 1007)	116	0.17	159	1	0.23
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	64	0.11	110	1	0.20
Lower Yellowstone River (code 1010)	103	0.09	376	3	0.32
Missouri-Little Missouri-Lake Sakakawea (code 1011)	196	0.06	360	3	0.11
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	381	0.05	819	6	0.11
Missouri-White River -Fort Randall Reservoir (code 1014)	247	0.09	385	3	0.14
Niobrara River Basin (code 1015)	94	0.07	116	1	0.09
James River Basin (code 1016)	298	0.04	765	5	0.11
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	758	0.13	648	5	0.11
North Platte River Basin (code 1018)	95	0.06	233	2	0.15
South Platte River Basin (code 1019)	52	0.01	376	3	0.09
Middle and Lower Platte River Basin (code 1020)	826	0.29	450	3	0.16
Loup River Basin (code 1021)	319	0.23	170	1	0.12
Elkhorn River Basin (code 1022)	812	0.31	352	3	0.13
Missouri-Little Sioux River Basin (code 1023)	1,562	0.33	722	5	0.15
Missouri-Nishnabotna River Basin (code 1024)	4,365	0.77	1,538	11	0.27
Republican River Basin (code 1025)	569	0.06	697	5	0.08
Smoky Hill River Basin (code 1026)	686	0.10	841	6	0.12
Kansas-Big Blue River Basin (code 1027)	2,588	0.52	1,030	7	0.21
Chariton-Grand River Basin (code 1028)	2,554	0.91	848	6	0.30
Gasconade-Osage River Basin (code 1029)	1,845	1.11	688	5	0.41
Lower Missouri-Lower Missouri-Blackwater (code 1030)	2,538	1.27	878	6	0.44
Regional total	21,839	0.23	14,032	100	0.15

* Loads delivered to rivers and streams also include wind erosion loads from cultivated cropland, which are not included in the edge-of-field amount.
Note: Loads represent both cropped acres and land in long-term conserving cover.
Note: Columns may not add to totals because of rounding.

Table 46. Sediment loads ***delivered to rivers and streams*** by source, baseline conservation condition, Missouri River Basin

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and rangeland	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 tons)			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	998	450	16	327	57	3	145
Missouri-Musselshell-Fort Peck Lake (code 1004)	300	208	<1	50	7	1	34
Milk River Basin (code 1005)	399	361	<1	17	8	1	12
Missouri-Poplar River Basin (code 1006)	479	453	0	3	14	1	8
Upper Yellowstone River Basin (code 1007)	556	161	9	247	23	4	113
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	1,297	111	41	650	29	7	460
Lower Yellowstone River (code 1010)	421	375	0	20	6	<1	20
Missouri-Little Missouri-Lake Sakakawea (code 1011)	398	360	<1	15	15	<1	7
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	1,021	819	1	69	62	3	67
Missouri-White River -Fort Randall Reservoir (code 1014)	447	385	<1	31	22	<1	9
Niobrara River Basin (code 1015)	233	116	<1	94	19	<1	5
James River Basin (code 1016)	824	765	4	3	50	1	<1
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	720	648	5	7	58	1	2
North Platte River Basin (code 1018)	463	233	14	124	20	4	68
South Platte River Basin (code 1019)	510	376	<1	15	68	26	26
Middle and Lower Platte River Basin (code 1020)	541	450	2	13	71	2	3
Loup River Basin (code 1021)	323	170	<1	124	23	<1	5
Elkhorn River Basin (code 1022)	402	351	<1	22	25	1	1
Missouri-Little Sioux River Basin (code 1023)	831	722	1	4	92	11	1
Missouri-Nishnabotna River Basin (code 1024)	1,740	1,538	8	24	160	5	6
Republican River Basin (code 1025)	758	697	<1	11	48	1	1
Smoky Hill River Basin (code 1026)	946	840	<1	24	78	1	3
Kansas-Big Blue River Basin (code 1027)	1,331	1,029	20	62	196	2	22
Chariton-Grand River Basin (code 1028)	1,122	848	60	61	128	<1	25
Gasconade-Osage River Basin (code 1029)	1,298	688	70	148	321	3	68
Lower Missouri-Lower Missouri-Blackwater (code 1030)	1,266	878	17	28	276	4	62
Regional total	19,624	14,032	271	2,192	1,875	82	1,173
				Percent of all sources			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	100	45	2	33	6	<1	14
Missouri-Musselshell-Fort Peck Lake (code 1004)	100	69	<1	17	2	<1	11
Milk River Basin (code 1005)	100	90	<1	4	2	<1	3
Missouri-Poplar River Basin (code 1006)	100	95	0	1	3	<1	2
Upper Yellowstone River Basin (code 1007)	100	29	2	44	4	1	20
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	100	9	3	50	2	1	35
Lower Yellowstone River (code 1010)	100	89	0	5	1	<1	5
Missouri-Little Missouri-Lake Sakakawea (code 1011)	100	91	<1	4	4	<1	2
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	100	80	<1	7	6	<1	7
Missouri-White River -Fort Randall Reservoir (code 1014)	100	86	<1	7	5	<1	2
Niobrara River Basin (code 1015)	100	49	<1	40	8	<1	2
James River Basin (code 1016)	100	93	1	<1	6	<1	<1
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	100	90	1	1	8	<1	<1
North Platte River Basin (code 1018)	100	50	3	27	4	1	15
South Platte River Basin (code 1019)	100	74	<1	3	13	5	5
Middle and Lower Platte River Basin (code 1020)	100	83	<1	2	13	<1	<1
Loup River Basin (code 1021)	100	53	<1	38	7	<1	2
Elkhorn River Basin (code 1022)	100	88	<1	6	6	<1	<1
Missouri-Little Sioux River Basin (code 1023)	100	87	<1	<1	11	1	<1
Missouri-Nishnabotna River Basin (code 1024)	100	88	<1	1	9	<1	<1
Republican River Basin (code 1025)	100	92	<1	1	6	<1	<1
Smoky Hill River Basin (code 1026)	100	89	<1	2	8	<1	<1
Kansas-Big Blue River Basin (code 1027)	100	77	1	5	15	<1	2
Chariton-Grand River Basin (code 1028)	100	76	5	5	11	<1	2
Gasconade-Osage River Basin (code 1029)	100	53	5	11	25	<1	5
Lower Missouri-Lower Missouri-Blackwater (code 1030)	100	69	1	2	22	<1	5
Regional total	100	72	1	11	10	<1	6

* Includes land in long-term conserving cover, excludes horticulture.

** Includes construction sources and urban land runoff.

*** Includes forests (all types), wetlands, horticulture, and barren land.

Table 47. Effects of conservation practices on average annual sediment loads ***delivered to rivers and streams from cultivated cropland,*** Missouri River Basin

Subregions	Baseline conservation condition (1,000 tons)	No-practice scenario (1,000 tons)	Reduction (1,000 tons)	Percent reduction
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	450	2,027	1,577	78
Missouri-Musselshell-Fort Peck Lake (code 1004)	208	765	557	73
Milk River Basin (code 1005)	361	1,464	1,103	75
Missouri-Poplar River Basin (code 1006)	454	1,591	1,138	71
Upper Yellowstone River Basin (code 1007)	159	441	282	64
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	110	315	205	65
Lower Yellowstone River (code 1010)	376	765	390	51
Missouri-Little Missouri-Lake Sakakawea (code 1011)	360	1,414	1,054	75
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	819	3,274	2,455	75
Missouri-White River -Fort Randall Reservoir (code 1014)	385	941	556	59
Niobrara River Basin (code 1015)	116	349	234	67
James River Basin (code 1016)	765	2,571	1,806	70
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	648	2,002	1,354	68
North Platte River Basin (code 1018)	233	1,286	1,053	82
South Platte River Basin (code 1019)	376	3,482	3,106	89
Middle and Lower Platte River Basin (code 1020)	450	2,340	1,890	81
Loup River Basin (code 1021)	170	948	778	82
Elkhorn River Basin (code 1022)	352	1,457	1,106	76
Missouri-Little Sioux River Basin (code 1023)	722	2,676	1,954	73
Missouri-Nishnabotna River Basin (code 1024)	1,538	7,329	5,791	79
Republican River Basin (code 1025)	697	5,168	4,471	87
Smoky Hill River Basin (code 1026)	841	2,534	1,694	67
Kansas-Big Blue River Basin (code 1027)	1,030	4,753	3,723	78
Chariton-Grand River Basin (code 1028)	848	4,001	3,153	79
Gasconade-Osage River Basin (code 1029)	688	1,854	1,166	63
Lower Missouri-Lower Missouri-Blackwater (code 1030)	878	3,007	2,129	71
Regional total	14,032	58,755	44,723	76

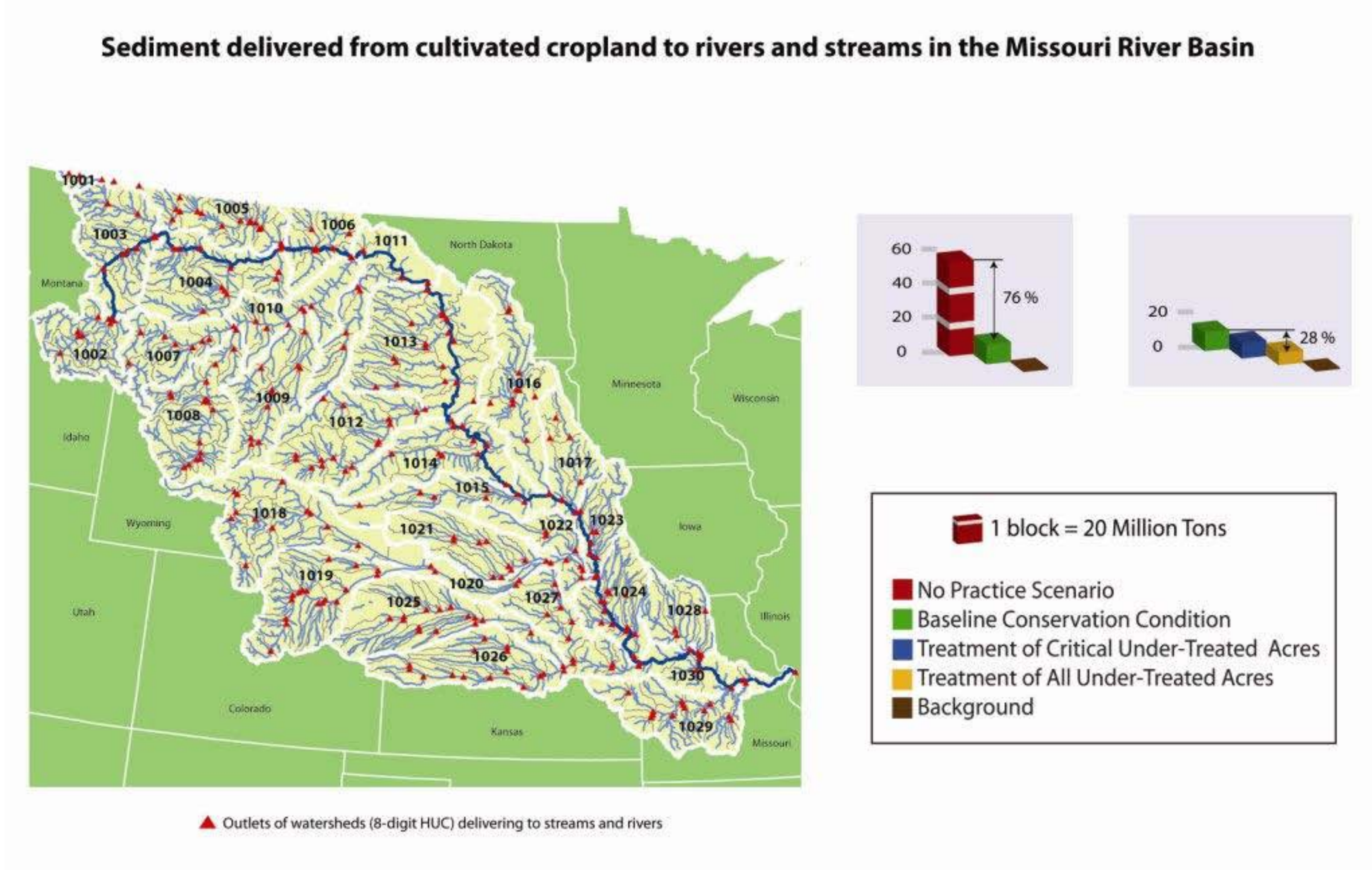
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 48. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual sediment loads ***delivered to rivers and streams*** from cultivated cropland, Missouri River Basin

		Treatment of all 15.3 million under-treated acres		
Subregions	Baseline conservation condition (1,000 tons)	Amount (1,000 tons)	Reduction (1,000 tons)	Percent reduction
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	450	409	40	9
Missouri-Musselshell-Fort Peck Lake (code 1004)	208	158	51	24
Milk River Basin (code 1005)	361	225	136	38
Missouri-Poplar River Basin (code 1006)	454	295	158	35
Upper Yellowstone River Basin (code 1007)	159	135	24	15
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	110	42	68	62
Lower Yellowstone River (code 1010)	376	82	294	78
Missouri-Little Missouri-Lake Sakakawea (code 1011)	360	318	43	12
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	819	706	113	14
Missouri-White River -Fort Randall Reservoir (code 1014)	385	385	0	0
Niobrara River Basin (code 1015)	116	78	37	32
James River Basin (code 1016)	765	667	99	13
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	648	602	46	7
North Platte River Basin (code 1018)	233	137	96	41
South Platte River Basin (code 1019)	376	108	268	71
Middle and Lower Platte River Basin (code 1020)	450	409	41	9
Loup River Basin (code 1021)	170	156	14	8
Elkhorn River Basin (code 1022)	352	221	131	37
Missouri-Little Sioux River Basin (code 1023)	722	558	164	23
Missouri-Nishnabotna River Basin (code 1024)	1,538	792	746	49
Republican River Basin (code 1025)	697	595	102	15
Smoky Hill River Basin (code 1026)	841	810	30	4
Kansas-Big Blue River Basin (code 1027)	1,030	706	324	31
Chariton-Grand River Basin (code 1028)	848	405	443	52
Gasconade-Osage River Basin (code 1029)	688	525	163	24
Lower Missouri-Lower Missouri-Blackwater (code 1030)	878	530	349	40
Regional total	14,032	10,053	3,978	28

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.
Note: Under-treated acres have either a “high” or “moderate” need for additional treatment.

Figure 95. Effects of conservation practices on average annual sediment loads delivered to rivers and streams, Missouri River Basin



Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources. In this graphic, however, only the loads delivered from cultivated cropland are shown; consequently, the background load is nearly negligible.

Total Nitrogen

Baseline condition. Model simulation results show that of the 656 million pounds of nitrogen exported from farm fields in the Missouri River Basin (table 49), about 500 million pounds are delivered to rivers and streams each year, on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 5.3 pounds per cultivated cropland acre are delivered to rivers and streams per year, on average, for the region (table 49).

The subregion with the largest amount of nitrogen delivered to rivers and streams from cultivated cropland annually is the Missouri-Nishnabotna subregion (code 1024)—53 million pounds per year. About 53 percent of the nitrogen delivered to rivers and streams from cultivated cropland originates in seven subregions—

- the Missouri-Nishnabotna (code 1024), with 11 percent,
- the Missouri-Big Sioux-Lewis-Clark River Basins (code 1017), with 8 percent,
- the Republican River Basin (code 1025), with 7 percent,
- the Kansas-Big Blue river Basin (code 1027), with 7 percent,
- the James River Basin (code 1016),with 7 percent,
- the Missouri-Little Sioux River Basin (code 1023), with 7 percent, and
- the Smoky Hill River Basin (code 1026), with 6 percent.

On a per-acre basis, nitrogen delivery to rivers and streams exceeds 10 pounds per cultivated cropland acre in four subregions, with the highest in the Lower Missouri River Basin (table 49)—

- the Lower Missouri River Basin (code 1030), with 12.6 pounds per acre,
- the Gasconade-Osage River Basin (code 1029), with 11.8 pounds per acre,
- the Elkhorn River Basin (code 1022), with 10.2 pounds per acre, and
- the Big Horn and Powder-Tongue River subregions (codes 1008 and 1009), with 10.1 pounds per acre.

These annual average rates of nitrogen delivery to rivers and streams within the region are lower than rates in other areas of the country. For example–

Region	Average annual pounds/acre/year of nitrogen delivered to rivers and streams from cultivated cropland
Missouri River Basin	5
Upper Mississippi River Basin	16.5
Ohio-Tennessee River Basin	19
Great Lakes Region	23
Chesapeake Bay Region	23

Nitrogen delivered to rivers and streams from cultivated cropland represents about 68 percent of the total nitrogen load delivered from all sources in the region (table 50, fig. 96). This percentage ranges, however, from a low of 18 percent in the Upper Yellowstone River Basin subregion (code 1007) to 89 percent or more in these four subregions—

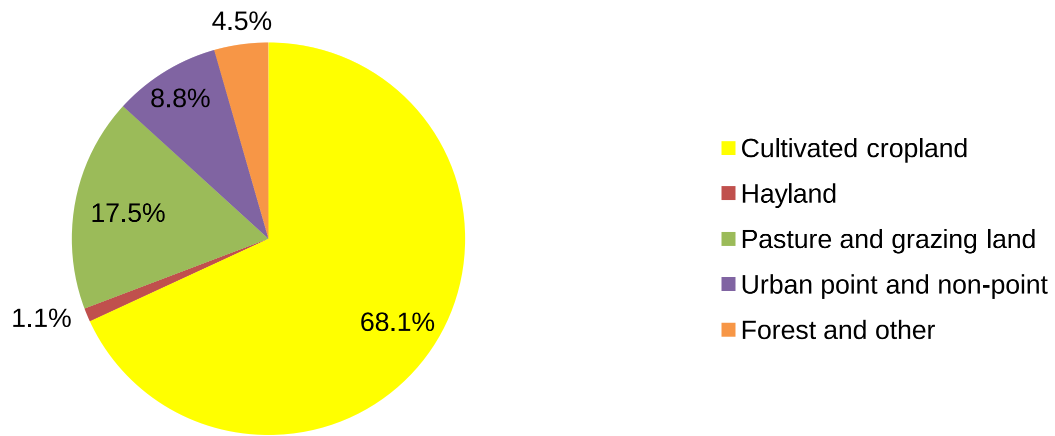
- the James River Basin (code 1016), with 96 percent,
- the Missouri-Big Sioux-Lewis-Clark River Basins (code 1017), with 94 percent.
- the Republican River Basin (code 1025), with 91 percent, and
- the Missouri-Nishnabotna (code 1024), with 89 percent.

Pastureland and rangeland account for 18 percent of the nitrogen loads delivered to rivers and streams within the region (table 50, fig. 96). Pastureland and rangeland account for over 50 percent of delivered nitrogen loads, however, in two subregions, both where contributions from cultivated cropland are low.

Urban point sources and urban runoff account for about 9 percent of the nitrogen delivered to rivers and streams in this region (table 50, fig. 96). Urban contributions are highest in the South Platte River Basin (code 1019), where point sources account for about 15 million pounds of nitrogen per year, representing 42 percent of the nitrogen delivered to rivers and streams in that subregion.

Hayland and forest and other land covers are minor contributors to nitrogen loads in most subregions.

Figure 96. Percentage by source of average annual nitrogen loads delivered to rivers and streams for the baseline conservation condition, Missouri River Basin



Effects of conservation practices. Nitrogen loads delivered to streams and rivers would have been much larger if conservation practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of nitrogen from fields to rivers and streams by about 54 percent (table 51, fig. 97), on average. Reductions due to conservation practices vary throughout the region, ranging from a low of 31 percent for the Lower Missouri River Basin (code 1030) to a high of 81 percent for the Missouri-Poplar River Basin (code 1006).

Potential gains from further conservation treatment. Because of the relatively low levels of nitrogen loss from farm fields throughout most of this region, the potential for additional gains from further conservation treatment is limited, as shown in figure 77 in the previous chapter. Nevertheless, model simulations show that use of additional conservation practices on the 15.3 million under-treated acres in the region would reduce overall nitrogen loads delivered to rivers and streams by about 435 million pounds per year, representing a reduction from baseline levels of 13 percent (table 52, fig. 97).

The largest gain in terms of pounds saved would occur in two subregions (table 52)—

- the Republican River Basin (code 1025), where 9.3 million pounds of nitrogen per year would be saved with additional conservation treatment, representing a 25-percent reduction from baseline levels, and
- the Missouri-Nishnabotna River Basin (code 1024), where 9.0 million pounds of nitrogen per year would be saved with additional conservation treatment, representing a 17-percent reduction from baseline levels.

In terms of percent reduction, five subregions would have nitrogen loads delivered to rivers and streams reduced by more than 30 percent (table 52)—

- the Big Horn and Powder-Tongue River Basins (codes 1008 and 1009), with a 67-percent reduction,
- the North Platte River Basin (code 1018), with a 55-percent reduction,
- the South Platte River Basin (code 1019), with a 36-percent reduction,
- the Lower Yellowstone River Basin (code 1010), with a 35-percent reduction, and
- the Upper Yellowstone River Basin (code 1007), with a 31-percent reduction.

Table 49. Average annual nitrogen loads at the ***edge of field*** (APEX model output) and ***delivered from cultivated cropland to rivers and streams*** for the baseline conservation condition, Missouri River Basin

	Edge-of-field loads		Delivered to rivers and streams		
Subregions	Amount (1,000 pounds)	Pounds per cultivated cropland acre	Amount (1,000 pounds)*	Percent of regional total	Pounds delivered per cultivated cropland acre
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	15,920	3.67	14,044	3	3.24
Missouri-Musselshell-Fort Peck Lake (code 1004)	7,499	3.08	6,894	1	2.83
Milk River Basin (code 1005)	4,085	1.20	5,636	1	1.66
Missouri-Poplar River Basin (code 1006)	5,343	1.39	6,684	1	1.74
Upper Yellowstone River Basin (code 1007)	3,518	5.14	3,158	1	4.62
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	7,047	12.50	5,719	1	10.15
Lower Yellowstone River (code 1010)	2,260	1.90	2,848	1	2.40
Missouri-Little Missouri-Lake Sakakawea (code 1011)	4,921	1.47	5,927	1	1.77
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	18,708	2.45	20,474	4	2.68
Missouri-White River -Fort Randall Reservoir (code 1014)	10,120	3.64	10,450	2	3.76
Niobrara River Basin (code 1015)	10,230	7.86	8,130	2	6.24
James River Basin (code 1016)	34,300	4.72	33,690	7	4.63
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	48,610	8.02	39,460	8	6.51
North Platte River Basin (code 1018)	10,520	6.63	9,280	2	5.85
South Platte River Basin (code 1019)	15,160	3.52	13,770	3	3.20
Middle and Lower Platte River Basin (code 1020)	30,030	10.46	21,960	4	7.65
Loup River Basin (code 1021)	15,050	10.95	11,220	2	8.16
Elkhorn River Basin (code 1022)	37,730	14.27	26,970	5	10.20
Missouri-Little Sioux River Basin (code 1023)	47,620	10.19	32,970	7	7.05
Missouri-Nishnabotna River Basin (code 1024)	87,960	15.58	52,940	11	9.38
Republican River Basin (code 1025)	43,260	4.81	37,250	7	4.14
Smoky Hill River Basin (code 1026)	31,970	4.74	28,000	6	4.15
Kansas-Big Blue River Basin (code 1027)	56,540	11.34	36,760	7	7.37
Chariton-Grand River Basin (code 1028)	37,570	13.36	21,320	4	7.58
Gasconade-Osage River Basin (code 1029)	27,690	16.66	19,640	4	11.82
Lower Missouri-Lower Missouri-Blackwater (code 1030)	42,100	21.08	25,190	5	12.61
Regional total	655,761	6.89	500,384	100	5.26

* Loads delivered to rivers and streams also include wind erosion loads from cultivated cropland, which are not included in the edge-of-field amount.
Note: Loads represent both cropped acres and land in long-term conserving cover.
Note: Columns may not add to totals because of rounding.

Table 50. Nitrogen loads ***delivered to rivers and streams*** by source, baseline conservation condition, Missouri River Basin

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and rangeland	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 pounds)			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	30,016	14,050	466	7,066	840	1,476	6,119
Missouri-Musselshell-Fort Peck Lake (code 1004)	15,103	6,896	23	5,528	216	655	1,787
Milk River Basin (code 1005)	8,493	5,637	1	1,896	154	681	125
Missouri-Poplar River Basin (code 1006)	8,330	6,685	<1	1,102	302	164	78
Upper Yellowstone River Basin (code 1007)	17,318	3,166	726	6,270	435	1,841	4,880
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	26,891	5,722	352	10,156	685	3,756	6,219
Lower Yellowstone River (code 1010)	6,262	2,849	<1	2,866	151	132	264
Missouri-Little Missouri-Lake Sakakawea (code 1011)	9,316	5,928	2	2,755	173	130	329
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	37,531	20,479	95	11,178	1,178	2,267	2,334
Missouri-White River -Fort Randall Reservoir (code 1014)	16,432	10,448	12	4,704	344	171	754
Niobrara River Basin (code 1015)	19,208	8,132	12	10,285	456	114	209
James River Basin (code 1016)	35,246	33,697	87	586	482	387	8
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	42,162	39,463	157	1,661	550	312	18
North Platte River Basin (code 1018)	19,993	9,282	338	5,088	417	1,937	2,932
South Platte River Basin (code 1019)	34,920	13,773	21	2,231	1,229	14,793	2,873
Middle and Lower Platte River Basin (code 1020)	27,536	21,959	23	3,708	550	1,214	81
Loup River Basin (code 1021)	28,036	11,225	27	15,846	563	222	152
Elkhorn River Basin (code 1022)	33,888	26,975	11	5,966	338	558	39
Missouri-Little Sioux River Basin (code 1023)	39,819	32,973	124	1,882	1,183	3,632	25
Missouri-Nishnabotna River Basin (code 1024)	59,823	52,950	580	2,901	1,323	1,969	101
Republican River Basin (code 1025)	40,776	37,257	9	1,983	803	701	23
Smoky Hill River Basin (code 1026)	32,952	28,007	12	3,491	823	538	81
Kansas-Big Blue River Basin (code 1027)	45,400	36,770	384	5,131	1,361	1,536	218
Chariton-Grand River Basin (code 1028)	28,905	21,324	1,836	3,900	1,285	200	360
Gasconade-Osage River Basin (code 1029)	34,486	19,641	2,037	6,708	2,398	1,995	1,707
Lower Missouri-Lower Missouri-Blackwater (code 1030)	36,104	25,201	929	4,056	3,093	1,834	992
Regional total	734,946	500,488	8,265	128,943	21,329	43,214	32,706
				Percent of all sources			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	100	47	2	24	3	5	20
Missouri-Musselshell-Fort Peck Lake (code 1004)	100	46	<1	37	1	4	12
Milk River Basin (code 1005)	100	66	<1	22	2	8	1
Missouri-Poplar River Basin (code 1006)	100	80	0	13	4	2	1
Upper Yellowstone River Basin (code 1007)	100	18	4	36	3	11	28
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	100	21	1	38	3	14	23
Lower Yellowstone River (code 1010)	100	45	0	46	2	2	4
Missouri-Little Missouri-Lake Sakakawea (code 1011)	100	64	<1	30	2	1	4
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	100	55	<1	30	3	6	6
Missouri-White River -Fort Randall Reservoir (code 1014)	100	64	<1	29	2	1	5
Niobrara River Basin (code 1015)	100	42	<1	54	2	1	1
James River Basin (code 1016)	100	96	<1	2	1	1	0
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	100	94	<1	4	1	1	0
North Platte River Basin (code 1018)	100	46	2	25	2	10	15
South Platte River Basin (code 1019)	100	39	<1	6	4	42	8
Middle and Lower Platte River Basin (code 1020)	100	80	<1	13	2	4	0
Loup River Basin (code 1021)	100	40	<1	57	2	1	1
Elkhorn River Basin (code 1022)	100	80	<1	18	1	2	0
Missouri-Little Sioux River Basin (code 1023)	100	83	<1	5	3	9	0
Missouri-Nishnabotna River Basin (code 1024)	100	89	1	5	2	3	0
Republican River Basin (code 1025)	100	91	<1	5	2	2	0
Smoky Hill River Basin (code 1026)	100	85	<1	11	2	2	0
Kansas-Big Blue River Basin (code 1027)	100	81	1	11	3	3	0
Chariton-Grand River Basin (code 1028)	100	74	6	13	4	1	1
Gasconade-Osage River Basin (code 1029)	100	57	6	19	7	6	5
Lower Missouri-Lower Missouri-Blackwater (code 1030)	100	70	3	11	9	5	3
Regional total	100	68	1	18	3	6	4

* Includes land in long-term conserving cover, excludes horticulture.

** Includes construction sources and urban land runoff.

*** Includes forests (all types), wetlands, horticulture, and barren land.

Table 51. Effects of conservation practices on average annual nitrogen loads ***delivered to rivers and streams from cultivated cropland,*** Missouri River Basin

Subregions	Baseline conservation condition (1,000 pounds)	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	14,044	43,338	29,294	68
Missouri-Musselshell-Fort Peck Lake (code 1004)	6,894	25,180	18,286	73
Milk River Basin (code 1005)	5,636	22,210	16,574	75
Missouri-Poplar River Basin (code 1006)	6,684	34,440	27,756	81
Upper Yellowstone River Basin (code 1007)	3,158	8,388	5,230	62
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	5,719	11,357	5,638	50
Lower Yellowstone River (code 1010)	2,848	10,960	8,112	74
Missouri-Little Missouri-Lake Sakakawea (code 1011)	5,927	24,710	18,783	76
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	20,474	76,094	55,620	73
Missouri-White River -Fort Randall Reservoir (code 1014)	10,450	23,080	12,630	55
Niobrara River Basin (code 1015)	8,130	19,550	11,420	58
James River Basin (code 1016)	33,690	78,370	44,680	57
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	39,460	66,100	26,640	40
North Platte River Basin (code 1018)	9,280	19,330	10,050	52
South Platte River Basin (code 1019)	13,770	41,250	27,480	67
Middle and Lower Platte River Basin (code 1020)	21,960	40,120	18,160	45
Loup River Basin (code 1021)	11,220	24,760	13,540	55
Elkhorn River Basin (code 1022)	26,970	45,540	18,570	41
Missouri-Little Sioux River Basin (code 1023)	32,970	48,660	15,690	32
Missouri-Nishnabotna River Basin (code 1024)	52,940	86,610	33,670	39
Republican River Basin (code 1025)	37,250	89,640	52,390	58
Smoky Hill River Basin (code 1026)	28,000	64,730	36,730	57
Kansas-Big Blue River Basin (code 1027)	36,760	60,300	23,540	39
Chariton-Grand River Basin (code 1028)	21,320	47,460	26,140	55
Gasconade-Osage River Basin (code 1029)	19,640	30,640	11,000	36
Lower Missouri-Lower Missouri-Blackwater (code 1030)	25,190	36,530	11,340	31
Regional total	500,384	1,079,347	578,963	54

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

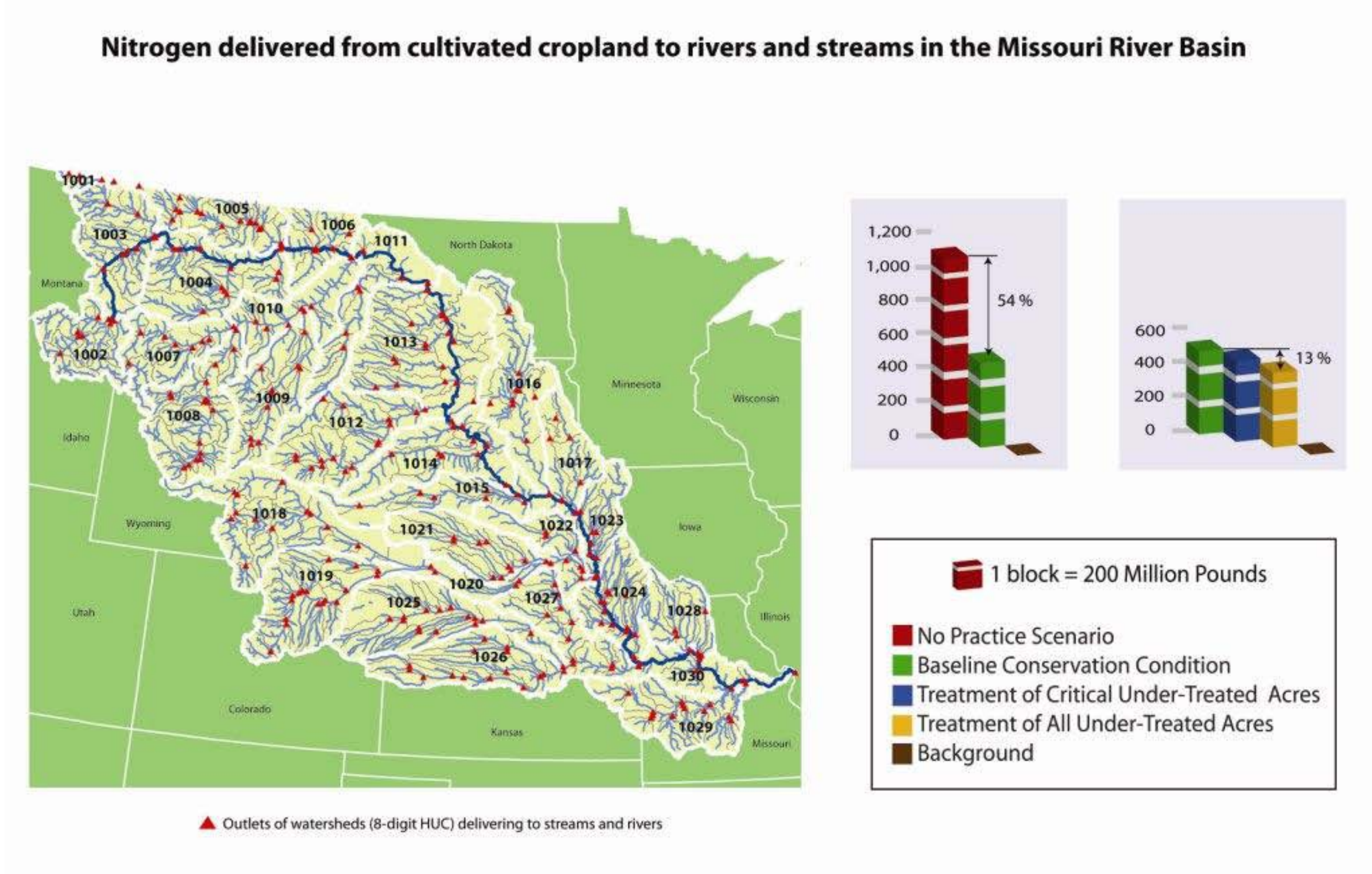
Table 52. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual nitrogen loads ***delivered to rivers and streams*** from cultivated cropland, Missouri River Basin

Subregions	Baseline conservation condition (1,000 pounds)	Treatment of all 15.3 million under-treated acres		
		Amount (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	14,044	13,292	752	5
Missouri-Musselshell-Fort Peck Lake (code 1004)	6,894	6,519	375	5
Milk River Basin (code 1005)	5,636	4,561	1,075	19
Missouri-Poplar River Basin (code 1006)	6,684	6,519	165	2
Upper Yellowstone River Basin (code 1007)	3,158	2,178	980	31
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	5,719	1,908	3,811	67
Lower Yellowstone River (code 1010)	2,848	1,857	991	35
Missouri-Little Missouri-Lake Sakakawea (code 1011)	5,927	5,551	376	6
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	20,474	17,765	2,709	13
Missouri-White River -Fort Randall Reservoir (code 1014)	10,450	10,350	100	1
Niobrara River Basin (code 1015)	8,130	6,494	1,636	20
James River Basin (code 1016)	33,690	31,860	1,830	5
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	39,460	38,160	1,300	3
North Platte River Basin (code 1018)	9,280	4,133	5,147	55
South Platte River Basin (code 1019)	13,770	8,795	4,975	36
Middle and Lower Platte River Basin (code 1020)	21,960	20,570	1,390	6
Loup River Basin (code 1021)	11,220	10,170	1,050	9
Elkhorn River Basin (code 1022)	26,970	21,320	5,650	21
Missouri-Little Sioux River Basin (code 1023)	32,970	29,840	3,130	9
Missouri-Nishnabotna River Basin (code 1024)	52,940	43,910	9,030	17
Republican River Basin (code 1025)	37,250	27,940	9,310	25
Smoky Hill River Basin (code 1026)	28,000	27,710	290	1
Kansas-Big Blue River Basin (code 1027)	36,760	34,210	2,550	7
Chariton-Grand River Basin (code 1028)	21,320	18,330	2,990	14
Gasconade-Osage River Basin (code 1029)	19,640	18,980	660	3
Lower Missouri-Lower Missouri-Blackwater (code 1030)	25,190	22,530	2,660	11
Regional total	500,384	435,452	64,932	13

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Note: Under-treated acres have either a “high” or “moderate” need for additional treatment.

Figure 97. Effects of conservation practices on average annual nitrogen loads delivered to rivers and streams, Missouri River Basin



Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources. In this graphic, however, only the loads delivered from cultivated cropland are shown; consequently, the background load is nearly negligible.

Total Phosphorus

Baseline condition. Model simulation results show that of the 56 million pounds of phosphorus exported from farm fields in the Missouri River Basin (table 53), about 33 million pounds are delivered to rivers and streams each year, on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 0.34 pounds per cultivated cropland acre is delivered to rivers and streams per year, on average, for the region (table 53).

The subregion with the largest amount of phosphorus delivered to rivers and streams from cultivated cropland annually is the Missouri-Nishnabotna subregion (code 1024)—4.6 million pounds per year (table 53). About 62 percent of the phosphorus delivered to rivers and streams from cultivated cropland originates in eight subregions—

- the Missouri-Nishnabotna (code 1024), with 14 percent,
- the Missouri-Little Sioux River Basin (code 1023), with 8 percent,
- the Lower Missouri River Basin (code 1030), with 7 percent.
- the Kansas-Big Blue river Basin (code 1027), with 7 percent,
- the Missouri-Big Sioux-Lewis-Clark River Basins (code 1017), with 7 percent,
- the Chariton-Grand river Basin (code 1028), with 7 percent,
- the Gasconade-Osage River Basin (code 1029), with 6 percent, and
- the James River Basin (code 1016), with 6 percent,

On a per-acre basis, phosphorus delivery to rivers and streams exceeds 0.8 pound per cultivated cropland acre in four subregions, with the highest in the Lower Missouri River Basin (table 53)—

- the Lower Missouri River Basin (code 1030), with 1.19 pounds per acre,
- the Gasconade-Osage River Basin (code 1029), with 1.15 pounds per acre,
- the Missouri-Nishnabotna (code 1024),with 0.82 pounds per acre, and
- the Chariton-Grand River Basin (code 1028), with 0.82 pounds per acre.

These annual average rates of phosphorus delivery to rivers and streams within the region are lower than rates in other areas of the country. For example–

Region	Average annual pounds/acre/year of phosphorus delivered to rivers and streams from cultivated cropland
Missouri River Basin	0.3
Upper Mississippi River Basin	1.3
Ohio-Tennessee River Basin	2.0
Great Lakes Region	1.2
Chesapeake Bay Region	1.5

Phosphorus delivered to rivers and streams from cultivated cropland represents about 46 percent of the total phosphorus load delivered from all sources in the region (table 54, fig. 98). This percentage ranges from a low of 5 percent in the South Platte River Basin (code 1019) to 80 percent or more in these four subregions—

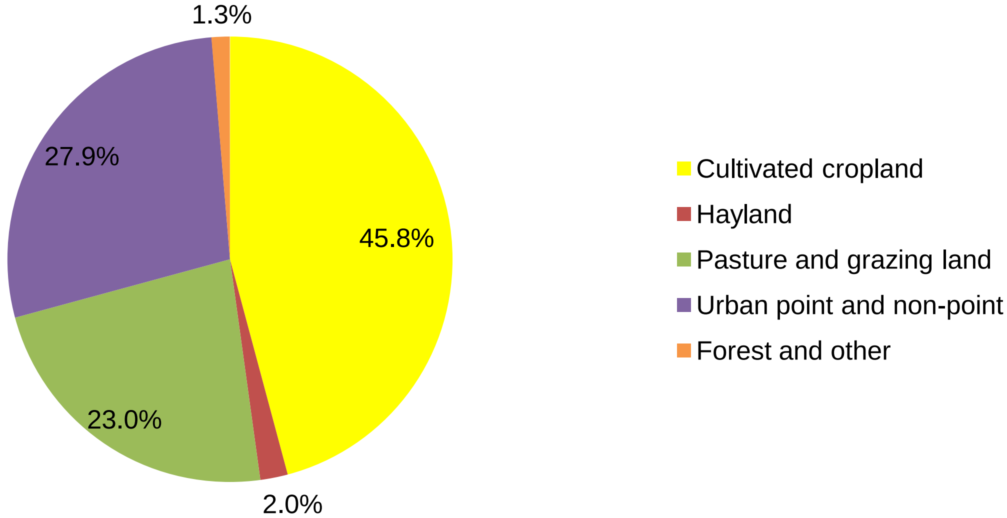
- the James River Basin (code 1016), with 84 percent,
- the Elkhorn River Basin (code 1022), with 82 percent,
- the Missouri-Big Sioux-Lewis-Clark River Basins (code 1017), with 81 percent.
- the Missouri-Poplar River Basin (code 1006), with 81 percent.

Pastureland and rangeland account for 23 percent of the phosphorus loads delivered to rivers and streams within the region (table 54, fig. 98). The percentage of phosphorus loads originating from pastureland and rangeland range from less than 1 percent to 50 percent (Gasconade-Osage River Basin, code 1029) among the subregions.

Urban point sources and urban runoff account for about 28 percent of the phosphorus delivered to rivers and streams in this region (table 54, fig. 98), primarily from point sources. Urban contributions are highest in the South Platte River Basin (code 1019), where point sources account for about 6.4 million pounds of phosphorus per year, representing 93 percent of the phosphorus delivered to rivers and streams in that subregion and 9 percent of phosphorus loads from all sources in the entire region.

Hayland and forest and other land covers are minor contributors to phosphorus loads in all subregions.

Figure 98. Percentage by source of average annual phosphorus loads delivered to rivers and streams for the baseline conservation condition, Missouri River Basin



Effects of conservation practices. Phosphorus loads delivered to streams and rivers would have been much larger if conservation practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of phosphorus from fields to rivers and streams by about 60 percent (table 55, fig. 99), on average. Reductions due to conservation practices vary throughout the region, ranging from a low of 36 percent for the Missouri-White River-Fort Randall Reservoir Basin (code 1014) to a high of 83 percent for the South Platte River Basin (code 1019).

Potential gains from further conservation treatment. Because of the relatively low levels of phosphorus loss from farm fields throughout most of this region, the potential for additional gains from further conservation treatment is limited, as shown in figure 77 in the previous chapter. Nevertheless, model simulations show that use of additional conservation practices on the 15.3 million under-treated acres in the region would reduce overall phosphorus loads delivered to rivers and streams by about 4.1 million pounds per year, representing a reduction from baseline levels of 12 percent (table 56, fig. 99).

The largest gain in terms of pounds saved would occur in the Missouri-Nishnabotna River Basin (code 1024), where 0.9 million pounds of phosphorus per year would be saved with additional conservation treatment, representing a 19-percent reduction from baseline levels.

In terms of percent reduction, four subregions would have phosphorus loads delivered to rivers and streams reduced by more than 40 percent (table 56)—

- the Big Horn and Powder-Tongue River Basins (codes 1008 and 1009), with a 67-percent reduction,
- the North Platte River Basin (code 1018), with a 64-percent reduction,
- the Lower Yellowstone River Basin (code 1010), with a 56-percent reduction, and
- the South Platte River Basin (code 1019), with a 45-percent reduction.

Table 53. Average annual phosphorus loads at the ***edge of field*** (APEX model output) and ***delivered from cultivated cropland to rivers and streams*** for the baseline conservation condition, Missouri River Basin

	Edge-of-field loads		Delivered to rivers and streams		
Subregions	Amount (1,000 pounds)	Pounds per cultivated cropland acre	Amount (1,000 pounds)*	Percent of regional total	Pounds delivered per cultivated cropland acre
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	1,238	0.29	1,064	3	0.25
Missouri-Musselshell-Fort Peck Lake (code 1004)	565	0.23	559	2	0.23
Milk River Basin (code 1005)	298	0.09	457	1	0.13
Missouri-Poplar River Basin (code 1006)	399	0.10	537	2	0.14
Upper Yellowstone River Basin (code 1007)	311	0.45	264	1	0.39
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	210	0.37	195	1	0.35
Lower Yellowstone River (code 1010)	126	0.11	264	1	0.22
Missouri-Little Missouri-Lake Sakakawea (code 1011)	397	0.12	469	1	0.14
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	1,319	0.17	1,538	5	0.20
Missouri-White River -Fort Randall Reservoir (code 1014)	661	0.24	672	2	0.24
Niobrara River Basin (code 1015)	245	0.19	194	1	0.15
James River Basin (code 1016)	1,604	0.22	1,876	6	0.26
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	3,166	0.52	2,328	7	0.38
North Platte River Basin (code 1018)	298	0.19	344	1	0.22
South Platte River Basin (code 1019)	149	0.03	369	1	0.09
Middle and Lower Platte River Basin (code 1020)	2,006	0.70	1,059	3	0.37
Loup River Basin (code 1021)	768	0.56	435	1	0.32
Elkhorn River Basin (code 1022)	2,461	0.93	1,356	4	0.51
Missouri-Little Sioux River Basin (code 1023)	4,668	1.00	2,465	8	0.53
Missouri-Nishnabotna River Basin (code 1024)	10,860	1.92	4,637	14	0.82
Republican River Basin (code 1025)	1,539	0.17	1,412	4	0.16
Smoky Hill River Basin (code 1026)	1,563	0.23	1,306	4	0.19
Kansas-Big Blue River Basin (code 1027)	5,611	1.13	2,346	7	0.47
Chariton-Grand River Basin (code 1028)	5,663	2.01	2,302	7	0.82
Gasconade-Osage River Basin (code 1029)	4,409	2.65	1,919	6	1.15
Lower Missouri-Lower Missouri-Blackwater (code 1030)	5,534	2.77	2,379	7	1.19
Regional total	56,067	0.59	32,746	100	0.34

* Loads delivered to rivers and streams also include wind erosion loads from cultivated cropland, which are not included in the edge-of-field amount.
Note: Loads represent both cropped acres and land in long-term conserving cover.
Note: Columns may not add to totals because of rounding.

Table 54. Phosphorus loads ***delivered to rivers and streams*** by source, baseline conservation condition, Missouri River Basin

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and rangeland	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 pounds)			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	2,648	1,064	25	838	79	549	93
Missouri-Musselshell-Fort Peck Lake (code 1004)	1,033	559	<1	207	7	250	10
Milk River Basin (code 1005)	775	457	<1	133	10	169	6
Missouri-Poplar River Basin (code 1006)	663	537	0	44	16	62	4
Upper Yellowstone River Basin (code 1007)	1,554	266	11	463	24	727	64
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	2,939	195	46	1,038	41	1,441	177
Lower Yellowstone River (code 1010)	436	264	<1	103	7	51	11
Missouri-Little Missouri-Lake Sakakawea (code 1011)	717	469	<1	175	19	48	5
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	3,262	1,539	2	859	82	747	34
Missouri-White River -Fort Randall Reservoir (code 1014)	1,140	672	2	364	32	65	5
Niobrara River Basin (code 1015)	423	194	<1	164	19	44	1
James River Basin (code 1016)	2,224	1,877	21	119	61	145	1
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	2,889	2,329	17	324	96	121	4
North Platte River Basin (code 1018)	1,468	344	19	218	22	841	24
South Platte River Basin (code 1019)	6,883	369	<1	27	71	6,410	7
Middle and Lower Platte River Basin (code 1020)	2,013	1,059	9	374	105	460	6
Loup River Basin (code 1021)	646	435	<1	108	22	81	0
Elkhorn River Basin (code 1022)	1,663	1,357	<1	72	29	206	0
Missouri-Little Sioux River Basin (code 1023)	4,038	2,466	4	164	121	1,281	2
Missouri-Nishnabotna River Basin (code 1024)	6,142	4,638	29	530	191	744	11
Republican River Basin (code 1025)	1,907	1,412	<1	158	49	287	1
Smoky Hill River Basin (code 1026)	2,305	1,307	1	656	116	222	4
Kansas-Big Blue River Basin (code 1027)	5,060	2,347	99	1,665	322	588	37
Chariton-Grand River Basin (code 1028)	4,955	2,302	341	1,906	258	76	72
Gasconade-Osage River Basin (code 1029)	7,932	1,920	572	3,939	522	737	242
Lower Missouri-Lower Missouri-Blackwater (code 1030)	5,758	2,380	216	1,768	573	697	124
Regional total	71,474	32,757	1,413	16,418	2,892	17,049	944
				Percent of all sources			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	100	40	1	32	3	21	4
Missouri-Musselshell-Fort Peck Lake (code 1004)	100	54	<1	20	1	24	1
Milk River Basin (code 1005)	100	59	<1	17	1	22	1
Missouri-Poplar River Basin (code 1006)	100	81	0	7	2	9	1
Upper Yellowstone River Basin (code 1007)	100	17	1	30	2	47	4
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	100	7	2	35	1	49	6
Lower Yellowstone River (code 1010)	100	61	<1	24	2	12	3
Missouri-Little Missouri-Lake Sakakawea (code 1011)	100	65	<1	24	3	7	1
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	100	47	<1	26	3	23	1
Missouri-White River -Fort Randall Reservoir (code 1014)	100	59	<1	32	3	6	0
Niobrara River Basin (code 1015)	100	46	<1	39	4	10	0
James River Basin (code 1016)	100	84	1	5	3	7	0
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	100	81	1	11	3	4	0
North Platte River Basin (code 1018)	100	23	1	15	1	57	2
South Platte River Basin (code 1019)	100	5	<1	<1	1	93	0
Middle and Lower Platte River Basin (code 1020)	100	53	<1	19	5	23	0
Loup River Basin (code 1021)	100	67	<1	17	3	12	0
Elkhorn River Basin (code 1022)	100	82	<1	4	2	12	0
Missouri-Little Sioux River Basin (code 1023)	100	61	<1	4	3	32	0
Missouri-Nishnabotna River Basin (code 1024)	100	76	<1	9	3	12	0
Republican River Basin (code 1025)	100	74	<1	8	3	15	0
Smoky Hill River Basin (code 1026)	100	57	<1	28	5	10	0
Kansas-Big Blue River Basin (code 1027)	100	46	2	33	6	12	1
Chariton-Grand River Basin (code 1028)	100	46	7	38	5	2	1
Gasconade-Osage River Basin (code 1029)	100	24	7	50	7	9	3
Lower Missouri-Lower Missouri-Blackwater (code 1030)	100	41	4	31	10	12	2
Regional total	100	46	2	23	4	24	1

* Includes land in long-term conserving cover, excludes horticulture.

** Includes construction sources and urban land runoff.

*** Includes forests (all types), wetlands, horticulture, and barren land.

Table 55. Effects of conservation practices on average annual phosphorus loads ***delivered to rivers and streams from cultivated cropland,*** Missouri River Basin

Subregions	Baseline conservation condition (1,000 pounds)	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	1,064	2,174	1,111	51
Missouri-Musselshell-Fort Peck Lake (code 1004)	559	937	377	40
Milk River Basin (code 1005)	457	1,001	544	54
Missouri-Poplar River Basin (code 1006)	537	1,130	593	52
Upper Yellowstone River Basin (code 1007)	264	489	224	46
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	195	381	186	49
Lower Yellowstone River (code 1010)	264	607	343	56
Missouri-Little Missouri-Lake Sakakawea (code 1011)	469	1,207	738	61
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	1,538	3,064	1,526	50
Missouri-White River -Fort Randall Reservoir (code 1014)	672	1,056	384	36
Niobrara River Basin (code 1015)	194	590	396	67
James River Basin (code 1016)	1,876	3,881	2,005	52
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	2,328	4,202	1,874	45
North Platte River Basin (code 1018)	344	1,344	1,000	74
South Platte River Basin (code 1019)	369	2,142	1,773	83
Middle and Lower Platte River Basin (code 1020)	1,059	3,800	2,741	72
Loup River Basin (code 1021)	435	1,616	1,181	73
Elkhorn River Basin (code 1022)	1,356	3,050	1,694	56
Missouri-Little Sioux River Basin (code 1023)	2,465	4,778	2,313	48
Missouri-Nishnabotna River Basin (code 1024)	4,637	11,720	7,083	60
Republican River Basin (code 1025)	1,412	4,655	3,243	70
Smoky Hill River Basin (code 1026)	1,306	3,171	1,865	59
Kansas-Big Blue River Basin (code 1027)	2,346	7,762	5,416	70
Chariton-Grand River Basin (code 1028)	2,302	6,910	4,608	67
Gasconade-Osage River Basin (code 1029)	1,919	4,299	2,380	55
Lower Missouri-Lower Missouri-Blackwater (code 1030)	2,379	5,227	2,848	54
Regional total	32,746	81,192	48,446	60

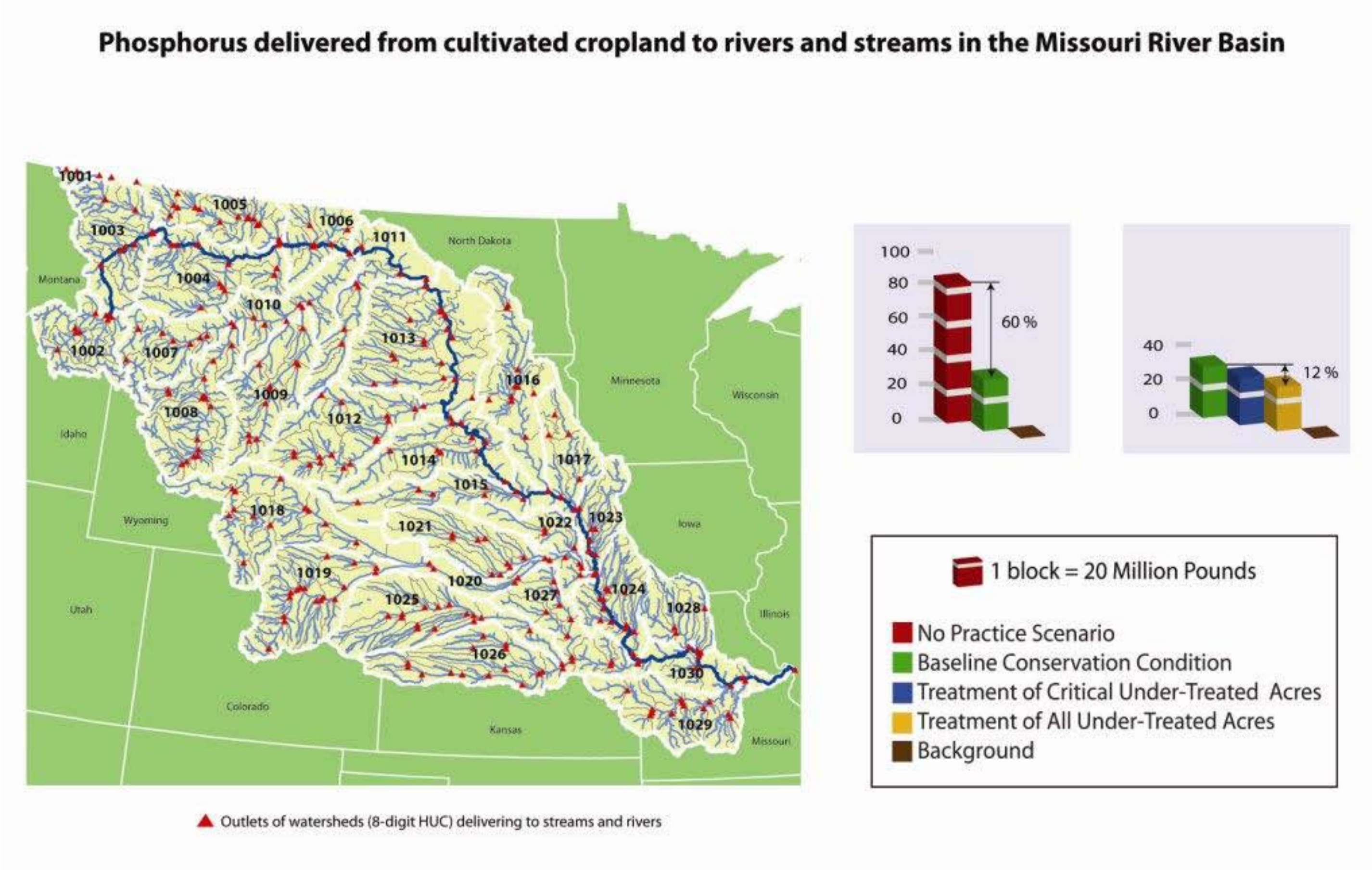
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 56. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual phosphorus loads ***delivered to rivers and streams*** from cultivated cropland, Missouri River Basin

		Treatment of all 15.3 million under-treated acres		
Subregions	Baseline conservation condition (1,000 pounds)	Amount (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	1,064	992	72	7
Missouri-Musselshell-Fort Peck Lake (code 1004)	559	494	65	12
Milk River Basin (code 1005)	457	365	93	20
Missouri-Poplar River Basin (code 1006)	537	537	0	0
Upper Yellowstone River Basin (code 1007)	264	160	104	39
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	195	64	130	67
Lower Yellowstone River (code 1010)	264	115	149	56
Missouri-Little Missouri-Lake Sakakawea (code 1011)	469	457	12	3
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	1,538	1,444	94	6
Missouri-White River -Fort Randall Reservoir (code 1014)	672	672	0	0
Niobrara River Basin (code 1015)	194	183	12	6
James River Basin (code 1016)	1,876	1,876	0	0
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	2,328	2,328	0	0
North Platte River Basin (code 1018)	344	122	222	64
South Platte River Basin (code 1019)	369	202	167	45
Middle and Lower Platte River Basin (code 1020)	1,059	919	140	13
Loup River Basin (code 1021)	435	430	5	1
Elkhorn River Basin (code 1022)	1,356	1,267	89	7
Missouri-Little Sioux River Basin (code 1023)	2,465	2,044	421	17
Missouri-Nishnabotna River Basin (code 1024)	4,637	3,734	903	19
Republican River Basin (code 1025)	1,412	1,291	121	9
Smoky Hill River Basin (code 1026)	1,306	1,266	40	3
Kansas-Big Blue River Basin (code 1027)	2,346	2,035	311	13
Chariton-Grand River Basin (code 1028)	2,302	1,854	448	19
Gasconade-Osage River Basin (code 1029)	1,919	1,790	129	7
Lower Missouri-Lower Missouri-Blackwater (code 1030)	2,379	2,054	325	14
Regional total	32,746	28,695	4,051	12

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.
Note: Under-treated acres have either a “high” or “moderate” need for additional treatment.

Figure 99. Effects of conservation practices on average annual phosphorus loads delivered to rivers and streams, Missouri River Basin



Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources. In this graphic, however, only the loads delivered from cultivated cropland are shown; consequently, the background load is nearly negligible.

Atrazine

Although the full suite of pesticides was modeled for edge-of-field losses, atrazine was the only pesticide for which instream loads were assessed because it was the dominant contributor to mass loss of pesticide residues from farm fields and the primary contributor to environmental risk from pesticides in the region. First registered in the United States in 1959, atrazine is used to control broadleaf and grassy weeds. Cultivated cropland (primarily corn acres) was the only source for atrazine in the model simulations.

Atrazine is not used as heavily in the Missouri River Basin as in some of the other regions of the country. Based on the 2003–06 CEAP survey findings, about 33 percent of cropped acres in the Missouri River Basin had atrazine applied in one or more years. Atrazine was used on 52 percent of cropped acres in the eastern portion of the basin but on only 19 percent of cropped acres in the western portion of the basin. For comparison, the Ohio-Tennessee River basin had atrazine applied to 71 percent of the cropped acres and the Upper Mississippi River Basin had atrazine applied to 60 percent of cropped acres. Atrazine use averaged 37 percent of cropped acres for all cultivated cropland in the country.

Baseline condition. Model simulation results show that of the 101,000 pounds of atrazine exported from farm fields in the Missouri River Basin (table 57), about 90,000 pounds are delivered to rivers and streams each year, on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006.

Delivery of atrazine to rivers and streams is insignificant in 19 of the 29 subregions, consisting of subregions with codes 1002 through 1019 plus 1025 and 1026, as shown in table 57. Altogether these 19 subregions account for only 9 percent of the atrazine delivered to rivers and streams in the region.

The Missouri-Nishnabotna (code 1024) delivers the most atrazine to rivers and streams—19,300 pounds per year (table 57), representing 21 percent of the atrazine delivered to rivers and streams within the region. Two other subregions deliver more than 10,000 pounds of atrazine per year—the Kansas-Big Blue River Basin (code 1027), with 17 percent of the region total, and the Lower Missouri River Basin (code 1030), with 15 percent of the region total.

Effects of conservation practices. Conservation practices—especially Integrated Pest Management (IPM) techniques and soil erosion control practices—can be effective in reducing the amount of atrazine lost from farm fields and delivered to rivers and streams. Model simulations indicate that conservation practices in this region have reduced the delivery of atrazine to rivers and streams by about 51,500 pounds per year, representing a reduction of 36 percent (table 58, fig. 100), on average. Among the subregions with significant atrazine use, reductions due to conservation practices range from 20 percent in the Gasconade-Osage River Basin (code 1029) to 49 percent in the Elkhorn River Basin (code 1022).

Potential gains from further conservation treatment. Model simulations show that use of additional conservation practices—primarily erosion control practices—on the 15.3 million under-treated acres in the region would reduce overall atrazine loads delivered to rivers and streams by about 4,200 pounds per year, representing a reduction from baseline levels of 5 percent (table 59, fig. 100). The largest gains would occur in the Missouri-Nishnabotna River Basin (code 1024).

Table 57. Average annual atrazine loads at the ***edge of field*** (APEX model output) and ***delivered from cultivated cropland to rivers and streams*** for the baseline conservation condition, Missouri River Basin

Subregions	Edge-of-field loads: Amount (1,000 pounds)	Edge-of-field loads: Pounds per cultivated cropland acre	Delivered to rivers and streams: Amount (1,000 pounds)*	Delivered to rivers and streams: Percent of regional total	Delivered to rivers and streams: Pounds delivered per cultivated cropland acre
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	0.0	0.000	0.0	0	0.000
Missouri-Musselshell-Fort Peck Lake (code 1004)	0.0	0.000	0.0	0	0.000
Milk River Basin (code 1005)	0.0	0.000	0.0	0	0.000
Missouri-Poplar River Basin (code 1006)	0.0	0.000	0.0	0	0.000
Upper Yellowstone River Basin (code 1007)	0.0	0.000	0.0	0	0.000
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	0.0	0.000	0.0	0	0.000
Lower Yellowstone River (code 1010)	0.0	0.000	0.0	0	0.000
Missouri-Little Missouri-Lake Sakakawea (code 1011)	<.05	<.001	<.05	0	<.001
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	0.1	<.001	0.1	0	<.001
Missouri-White River -Fort Randall Reservoir (code 1014)	0.4	<.001	0.4	0	<.001
Niobrara River Basin (code 1015)	0.8	0.001	0.7	1	0.001
James River Basin (code 1016)	1.6	<.001	1.6	2	<.001
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	1.6	<.001	1.4	2	<.001
North Platte River Basin (code 1018)	0.1	<.001	0.1	0	<.001
South Platte River Basin (code 1019)	0.2	<.001	0.2	0	<.001
Middle and Lower Platte River Basin (code 1020)	7.4	0.003	6.8	7	0.002
Loup River Basin (code 1021)	3.1	0.002	2.9	3	0.002
Elkhorn River Basin (code 1022)	2.9	0.001	2.5	3	0.001
Missouri-Little Sioux River Basin (code 1023)	5.5	0.001	4.8	5	0.001
Missouri-Nishnabotna River Basin (code 1024)	22.6	0.004	19.3	21	0.003
Republican River Basin (code 1025)	1.9	<.001	1.8	2	<.001
Smoky Hill River Basin (code 1026)	2.0	<.001	1.8	2	<.001
Kansas-Big Blue River Basin (code 1027)	16.8	0.003	15.3	17	0.003
Chariton-Grand River Basin (code 1028)	10.5	0.004	9.3	10	0.003
Gasconade-Osage River Basin (code 1029)	8.4	0.005	7.6	8	0.005
Lower Missouri-Lower Missouri-Blackwater (code 1030)	14.9	0.007	13.6	15	0.007
Regional total	100.9	0.001	90.3	100	0.001

* Loads delivered to rivers and streams also include wind erosion loads from cultivated cropland, which are not included in the edge-of-field amount.
Note: Loads represent both cropped acres and land in long-term conserving cover.
Note: Columns may not add to totals because of rounding.

Table 58. Effects of conservation practices on average annual atrazine loads ***delivered to rivers and streams from cultivated cropland,*** Missouri River Basin

Subregions*	Baseline conservation condition (1,000 pounds)	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Middle and Lower Platte River Basin (code 1020)	6.8	10.3	3.5	34
Loup River Basin (code 1021)	2.9	5.5	2.6	47
Elkhorn River Basin (code 1022)	2.5	4.9	2.4	49
Missouri-Little Sioux River Basin (code 1023)	4.8	7.4	2.6	35
Missouri-Nishnabotna River Basin (code 1024)	19.3	26.3	7.0	26
Kansas-Big Blue River Basin (code 1027)	15.3	24.2	8.9	37
Chariton-Grand River Basin (code 1028)	9.3	16.9	7.7	45
Gasconade-Osage River Basin (code 1029)	7.6	9.6	2.0	20
Lower Missouri-Lower Missouri-Blackwater (code 1030)	13.6	17.3	3.7	21
All other subregions	8.1	19.4	11.3	58
Regional total	90.3	141.7	51.5	36

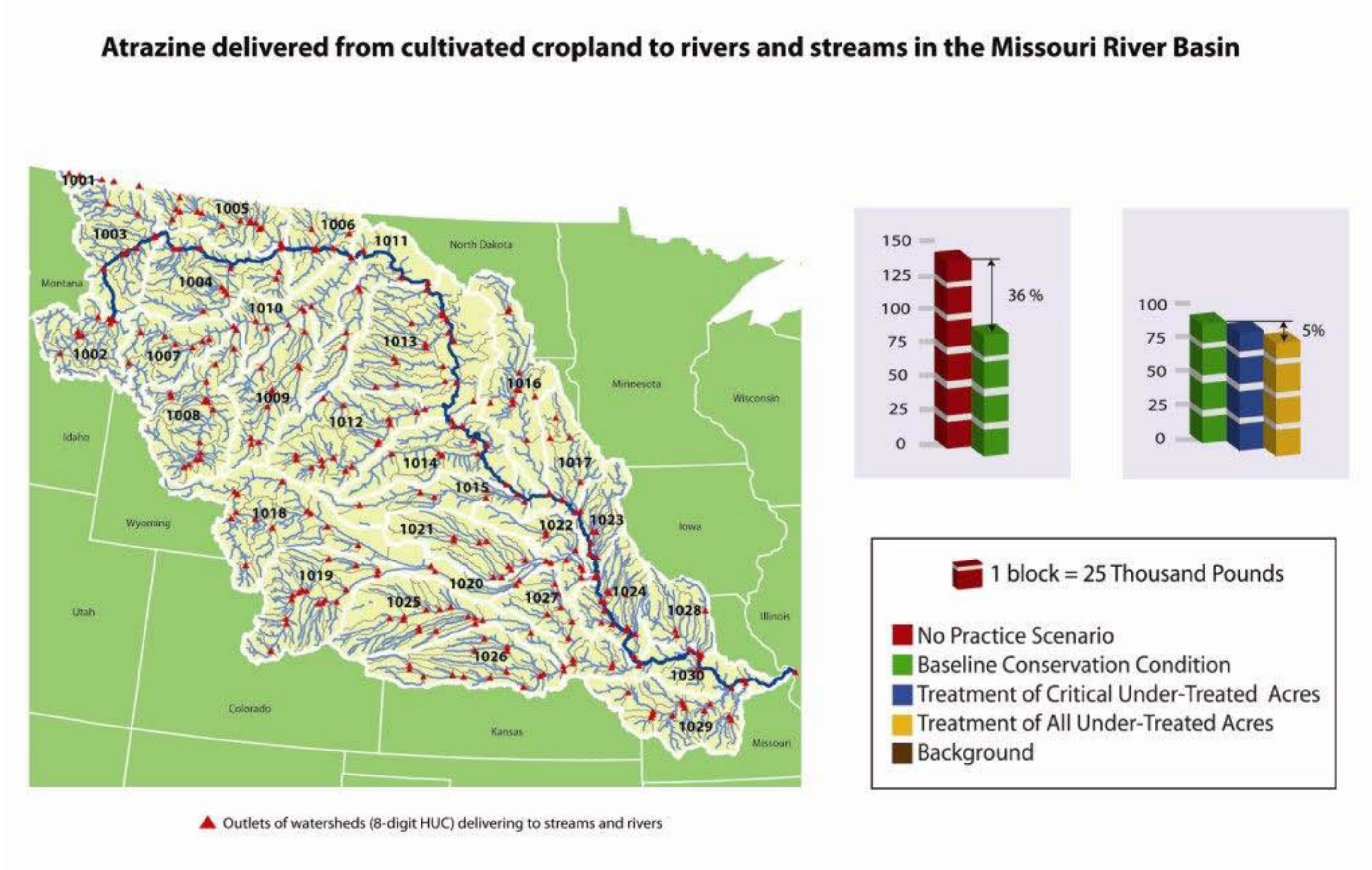
***** Only subregions with significant atrazine use are shown.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 59. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual atrazine loads ***delivered to rivers and streams*** from cultivated cropland, Missouri River Basin

		Treatment of all 15.3 million under-treated acres		
Subregions*	Baseline conservation condition (1,000 pounds)	Amount (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Middle and Lower Platte River Basin (code 1020)	6.8	6.1	0.7	10
Loup River Basin (code 1021)	2.9	2.8	0.1	3
Elkhorn River Basin (code 1022)	2.5	2.4	0.1	5
Missouri-Little Sioux River Basin (code 1023)	4.8	4.7	0.1	2
Missouri-Nishnabotna River Basin (code 1024)	19.3	17.7	1.7	9
Kansas-Big Blue River Basin (code 1027)	15.3	14.8	0.5	3
Chariton-Grand River Basin (code 1028)	9.3	8.8	0.4	5
Gasconade-Osage River Basin (code 1029)	7.6	7.6	<0.1	<1
Lower Missouri-Lower Missouri-Blackwater (code 1030)	13.6	13.2	0.4	3
All other subregions	8.1	7.9	0.2	2
Regional total	90.3	86.1	4.2	5

***** Only subregions with significant atrazine use are shown.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.
Note: Under-treated acres have either a “high” or “moderate” need for additional treatment.

Figure 100. Effects of conservation practices on average annual atrazine loads delivered to rivers and streams, Missouri River Basin



Note: Cultivated cropland is the only source of atrazine included in the modeling; consequently, “background sources” are zero for atrazine.

Subregions delivering the most sediment, nutrients, and atrazine to rivers and streams

There are 10 subregions within the Missouri River Basin that model simulations show have the largest shares of the region's total loads delivered from cultivated cropland to rivers and streams of sediment, nitrogen, phosphorus, *and* atrazine. For example, the Missouri-Nishnabotna subregion (code 1024) consistently delivers more sediment, nitrogen, phosphorus, *and* atrazine than any of the other 28 subregions, as shown previously.

Nine other subregions also are among the subregions that consistently deliver more of the four constituents (sediment, nitrogen, phosphorus, or atrazine) to rivers and streams than other subregions (table 60). These "top 10" subregions, which represent 57 percent of the cropped acres in the region, account for—

- 62 percent of the sediment delivered from cultivated cropland to rivers and streams,
- 65 percent of the nitrogen delivered from cultivated cropland to rivers and streams,
- 70 percent of the phosphorus delivered from cultivated cropland to rivers and streams, and
- 85 percent of the atrazine delivered from cultivated cropland to rivers and streams.

The "top 10" subregions are all located in the eastern and southern parts of the Missouri River Basin (fig. 101). These 10 subregions also have 83 percent of the acres with a "high" need for additional conservation treatment and 41 percent of the acres with a "moderate" need for additional treatment. Most of the remaining acres with a "moderate" need for treatment are acres in the western portion of the basin that need additional treatment for wind erosion or nitrogen loss in subsurface flows.

Table 60. Summary of the percent of regional total by subregion for sediment, nitrogen, phosphorus, and atrazine loads ***delivered from cultivated cropland to rivers and streams*** for the baseline conservation condition, Missouri River Basin

	Percent of regional total for each constituent			
Subregions	Sediment	Nitrogen	Phosphorus	Atrazine
	Subregions* not *in the top ten			
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	3	3	3	0
Missouri-Musselshell-Fort Peck Lake (code 1004)	1	1	2	0
Milk River Basin (code 1005)	3	1	1	0
Missouri-Poplar River Basin (code 1006)	3	1	2	0
Upper Yellowstone River Basin (code 1007)	1	1	1	0
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	1	1	1	0
Lower Yellowstone River (code 1010)	3	1	1	0
Missouri-Little Missouri-Lake Sakakawea (code 1011)	3	1	1	0
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)	6	4	5	0
Missouri-White River -Fort Randall Reservoir (code 1014)	3	2	2	0
Niobrara River Basin (code 1015)	1	2	1	1
North Platte River Basin (code 1018)	2	2	1	0
South Platte River Basin (code 1019)	3	3	1	0
Middle and Lower Platte River Basin (code 1020)	3	4	3	7
Loup River Basin (code 1021)	1	2	1	3
Elkhorn River Basin (code 1022)	3	5	4	3
Subtotal	38	35	30	15
	Subregions in the top ten			
James River Basin (code 1016)	5	7	6	2
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	5	8	7	2
Missouri-Little Sioux River Basin (code 1023)	5	7	8	5
Missouri-Nishnabotna River Basin (code 1024)	11	11	14	21
Republican River Basin (code 1025)	5	7	4	2
Smoky Hill River Basin (code 1026)	6	6	4	2
Kansas-Big Blue River Basin (code 1027)	7	7	7	17
Chariton-Grand River Basin (code 1028)	6	4	7	10
Gasconade-Osage River Basin (code 1029)	5	4	6	8
Lower Missouri-Lower Missouri-Blackwater (code 1030)	6	5	7	15
Subtotal	62	65	70	85
Regional total	100	100	100	100

Note: Percentages are taken from tables 45, 49, 53, and 57. Percentages may not add to totals due to rounding.

Figure 101. The 10 subregions with the highest overall sediment, nutrient, and pesticide loads delivered from cultivated cropland to rivers and streams, Missouri River Basin

Instream Loads from All Sources

Instream loads are estimated by starting with the loads delivered from all sources at the outlet of each 8-digit HUC and routing those loads downstream. Stream and channel processes are simulated, including flood routing, instream degradation processes, streambed deposition, streambank erosion, and reservoir dynamics. A portion of the sediment, nutrients, and pesticides delivered to rivers and streams is removed or trapped during these processes. Some of the nitrogen is lost during instream nitrification processes, and a portion of the sediment and sediment-bound nutrients and pesticides is deposited in streambeds and flood plains during transit. Large reservoirs can trap significant amounts of loads delivered to rivers and streams, keeping those loads from being transferred downstream. Sediment can also be added to instream loads through streambank erosion and streambed scouring.

In summary, findings for the Missouri River Basin indicate that instream ***loads from all sources delivered from the region to the Mississippi River*** *per year, on average, are:*

- *44 million tons of sediment (22 percent attributable to cultivated cropland sources);*
- *511 million pounds of nitrogen (67 percent attributable to cultivated cropland sources);*
- *55 million pounds of phosphorus (32 percent attributable to cultivated cropland sources); and*
- *61,000 pounds of atrazine;*

Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced ***instream loads from all sources delivered from the region to the Mississippi River*** *per year, on average, by:*

- *4 percent for sediment;*
- *36 percent for nitrogen;*
- *28 percent for phosphorus, and*
- *32 percent for atrazine.*

Additional conservation treatment of the 15.3 million under-treated acres in the region would be expected to further reduce ***instream loads from all sources delivered from the region to the Mississippi River*** *per year relative to the baseline, on average, by:*

- *1 percent for sediment;*
- *6 percent for nitrogen;*
- *4 percent for phosphorus, and*
- *4 percent for atrazine.*

Sediment

Baseline condition. Sediment loads delivered to rivers and streams from all sources totaled about 19.6 million tons per year (table 46), averaged over the 47 years of weather as simulated in the model. Instream sediment loads delivered to the Mississippi River near Hermann, MO, after accounting for instream deposition, reservoir dynamics, streambank erosion, and other transport processes, was much higher—about 44 million tons per year (table 61). The increase in sediment loadings is attributed to instream sediment sources including primarily streambank and bed erosion. More than half of the sediment delivered to the Mississippi River (24.4 million tons of sediment per year) comes through instream sediment sources including streambank erosion.

About 22 percent of the instream sediment load delivered to the Mississippi River is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the "background" scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 61).

The largest contribution of instream sediment loads among tributary subregions is from the Lower Yellowstone River (code 1010), with 12.9 million tons per year; however, only about 0.4 million tons are from cultivated cropland sources (table 61). The second largest contribution is from the Middle and Lower Platte River Basin (code 1020), with 8.3 million tons of which 35 percent are attributable to cultivated cropland. Other tributary subregions with high percentage of instream loads attributable to cultivated cropland are the Elkhorn River Basin (code 1022) with 59 percent and the James River Basin (code 1016) with 40 percent.

The instream loads for outlets along the mainstem include both sediment loads from upstream sources and additional loads contributed from within the subregion. In general these mainstem loads are smallest near the headwaters and largest near the outlet of the Missouri River as the loads accumulate moving downstream. The presence of lakes and reservoirs along the mainstem of the river disrupt this trend when significant amounts of sediment are trapped within those water bodies. Instream load estimates presented in table 61 for three mainstem subregions demonstrate the extent to which lakes and reservoirs along the Missouri River mainstem reduce instream loadings—

- the Missouri-Musselshell-Fort Peck Lake (code 1004)
- the Missouri-Little Missouri-Lake Sakakawea (code 1011)
- the Missouri-White River-Fort Randall Reservoir (code 1014)

Sediment deposition in the major reservoirs along the main stem of the Missouri River has a profound impact on sediment loading. The vast majority of sediments from the northwestern portion of the basin is trapped in these reservoirs and never reaches the Mississippi. Collectively, the reservoirs from Fort Peck Reservoir to Gavin's Point along the Missouri trap 99 percent of the sediment originating above Fort Peck.

Effects of conservation practices.
Model simulations of instream loads indicate that conservation practices have reduced the delivery of sediment from the Missouri River Basin to the Mississippi River by about 4 percent overall (table 61 and fig. 102). Without conservation practices, the total sediment delivered to the Mississippi River would be larger by 1.6 million tons per year.

Several processes in the Missouri River Basin contribute to the relatively small impact of conservation practices at the outlet of the Missouri River. The Missouri Basin is has six major reservoirs (fig. 91) that trap significant amounts of cultivated land sediment, nitrogen, phosphorus, and atrazine from cultivated cropland before these materials can reach the Mississippi River. After leaving the final reservoir (Gavin's Point), the relatively clear water has significant potential for scour, and significant streambank and bed erosion occurs between Gavin's Point and the confluence of the Mississippi River, further limiting the relative impact of upstream conservation practices.

Larger reductions, however, occur among the tributary subregions. The total reduction in instream loads for the 17 tributary subregions due to conservation practices is 5.1 million tons, representing about a 10-percent reduction (table 61).

Potential gains from further conservation treatment.
Because of the relatively low levels of water-eroded sediment loss from farm fields throughout most of this region and the relatively large contributions of sediment from sources other than cultivated cropland, the potential for reductions in instream loads from further conservation treatment is low for this region, as shown in table 61 and figure 102. Treatment of the 15.3 million under-treated acres in the region with additional erosion control practices would be expected to reduce instream loads delivered to the Mississippi River by only about 1 percent. Somewhat higher instream load reductions could occur, however, among the tributary subregions.

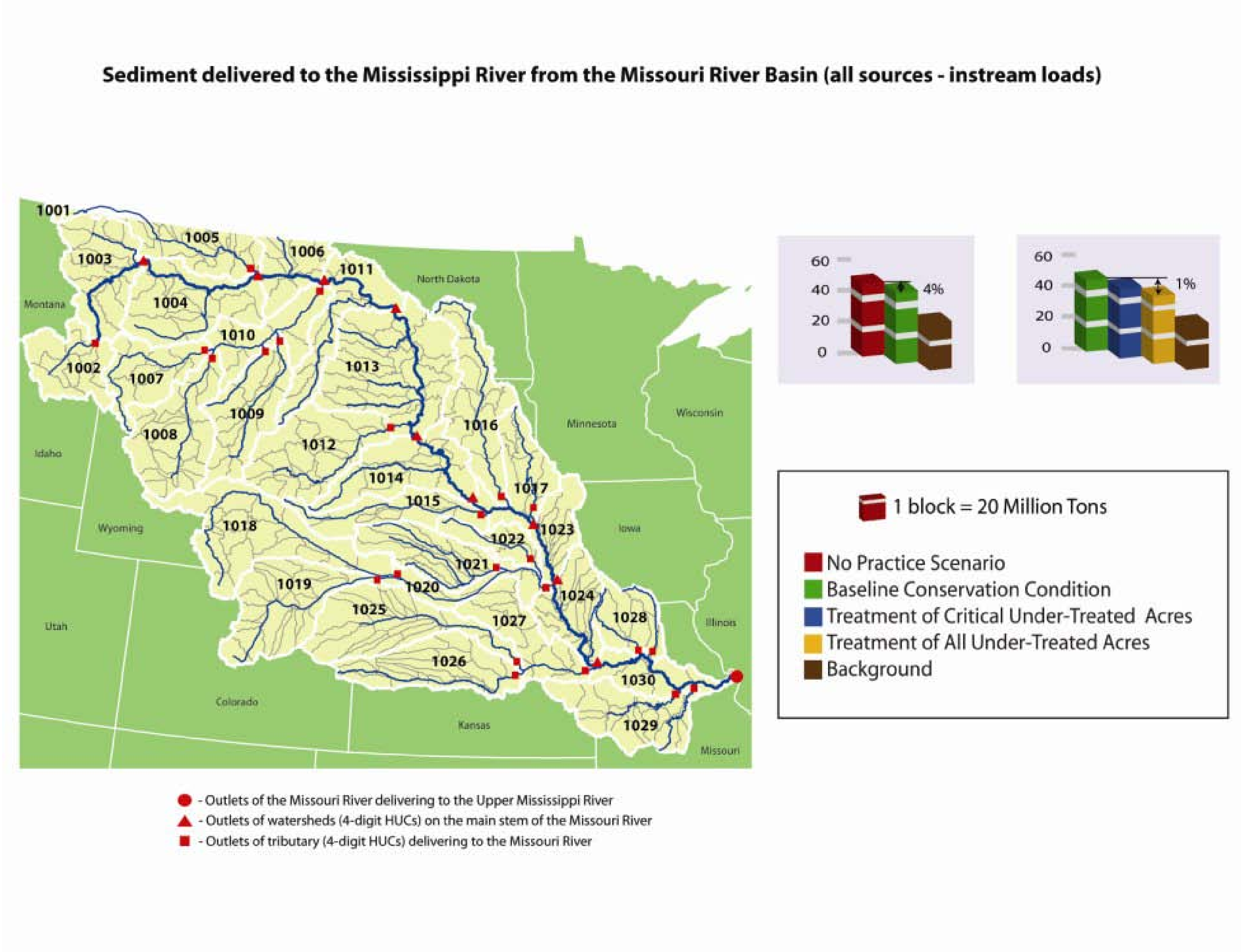
Table 61. Average annual ***instream sediment loads*** (all sources) for the baseline conservation condition, no-practice scenario, and the erosion control with nutrient management treatment scenario, Missouri River Basin

Subregions	Baseline conservation condition: Load from all sources (1,000 tons)	Baseline conservation condition: Background sources** (1,000 tons)	Baseline conservation condition: Percent of load attributed to cultivated cropland sources	No-practice scenario: Load from all sources (1,000 tons)	No-practice scenario: Reductions due to conservation practices (1,000 tons)	No-practice scenario: Percent reduction	Additional conservation treatment for all 15.3 million under-treated acres: Load from all sources (1,000 tons)	Additional conservation treatment for all 15.3 million under-treated acres: Reductions from baseline due to additional conservation treatment (1,000 tons)	Additional conservation treatment for all 15.3 million under-treated acres: Percent reduction
Tributary subregions									
Milk River Basin (code 1005)	120	104	13	183	63	35	111	9	7
Upper Yellowstone River Basin (code 1007)	2,178	2,100	4	2,308	130	6	2,158	20	1
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	4,649	4,562	2	4,722	73	2	4,605	43	1
Lower Yellowstone River (code 1010)	12,860	12,490	3	13,060	200	2	12,650	210	2
Cheyenne River (code 1012)	860	819	5	891	30	3	859	1	0
Niobrara River Basin (code 1015)	1,168	1,024	12	1,245	77	6	1,165	3	0
James River Basin (code 1016)	782	473	40	1,018	236	23	771	11	1
North Platte River Basin (code 1018)	586	462	21	779	192	25	537	50	8
South Platte River Basin (code 1019)	1,684	1,381	18	2,482	798	32	1,562	122	7
Middle and Lower Platte River Basin (code 1020)	8,321	5,425	35	9,497	1,176	12	8,009	312	4
Loup River Basin (code 1021)	1,198	910	24	1,342	144	11	1,192	6	1
Elkhorn River Basin (code 1022)	933	387	59	1,210	277	23	894	39	4
Republican River Basin (code 1025)	624	514	18	884	260	29	623	1	0
Smoky Hill River Basin (code 1026)	574	540	6	763	189	25	573	1	0
Kansas-Big Blue River Basin (code 1027)	5,046	4,158	18	5,704	658	12	5,021	25	0
Chariton-Grand River Basin (code 1028)	2,302	1,853	20	2,884	582	20	2,215	87	4
Gasconade-Osage River Basin (code 1029)	2,248	2,064	8	2,272	24	1	2,247	1	0
Outlets along mainstem									
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	3,072	2,917	4	3,440	368	11	3,056	16	1
Missouri-Musselshell-Fort Peck Lake (code 1004)	907	905	0	915	8	1	906	1	0
Missouri-Poplar River Basin (code 1006)	3,643	3,455	5	4,033	390	10	3,571	72	2
Missouri-Little Missouri-Lake Sakakawea (code 1011)	1,063	1,063	0	1,063	0	0	1,063	0	0
Missouri-Grand-Moreau-Lake Oahe (code 1013)	9,387	9,200	2	9,684	297	3	9,372	15	0
Missouri-White River -Fort Randall Reservoir (code 1014)	7,032	6,820	3	7,256	224	3	7,026	6	0
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	9,987	9,157	8	10,570	583	6	9,961	26	0
Missouri-Little Sioux River Basin (code 1023)	16,810	14,870	12	17,080	270	2	16,760	50	0
Missouri-Nishnabotna River Basin (code 1024)	27,650	20,380	26	29,400	1,750	6	27,120	530	2
Load delivered to the Mississippi River (code 1030)	44,010	34,210	22	45,620	1,610	4	43,620	390	1

****** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 102. Effects of conservation practices on average annual instream sediment loads, Missouri River Basin



Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Total Nitrogen

Baseline condition. Nitrogen loads delivered to rivers and streams from all sources totaled about 735 million pounds per year (table 50). Instream nitrogen loads delivered to the Mississippi River, after accounting for instream deposition, reservoir dynamics, and other transport processes, was much lower, totaling about 511 million pounds per year, averaged over the 47 years of weather as simulated in the model (table 62).

About 67 percent of the instream nitrogen load delivered to the Mississippi River is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the “background” scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 62).

The largest contribution of instream nitrogen loads among tributary subregions is from the Middle and Lower Platte River Basin (code 1020), with 97 million pounds per year; about 65 percent of these loads are from cultivated cropland sources (table 62).

Tributary subregions with the highest percentages of instream loads attributable to cultivated cropland are: the James River Basin (code 1016) with 95 percent; the Republican River Basin (code 1025)with 90 percent, and the Elkhorn River Basin (code 1022) with 79 percent.

The instream loads for outlets along the mainstem include nitrogen loads from upstream sources and additional loads contributed from within the subregion. In general these mainstem loads are smallest near the headwaters and largest near the outlet of the Missouri River. The presence of lakes and reservoirs along the mainstem of the river disrupt this trend, as was shown for instream sediment loads (table 62). Instream loads increase dramatically—10 fold—over the four most downstream subregions along the mainstem, demonstrating that the bulk of nitrogen loads are coming from subregions that discharge into the lower one-third of the Missouri River.

Effects of conservation practices.
Model simulations of instream loads indicate that conservation practices have reduced the delivery of nitrogen from the Missouri River Basin to the Mississippi River by about 36 percent overall (table 62 and fig. 103). Without conservation practices, the total nitrogen delivered to the Mississippi River would be larger by 282 million pounds per year. Percent reductions are higher for most subregions, including other subregions along the mainstem.

The largest reduction among the tributary subregions is for the Middle and Lower Platte River Basin (code 1020), where over 60 million pounds per year of the instream nitrogen load has been reduced due to conservation practices.

Potential gains from further conservation treatment.
The potential for reductions in instream nitrogen loads from further conservation treatment is somewhat larger than for sediment or phosphorus, as shown in table 62 and figure 103. Treatment of the 15.3 million under-treated acres in the region with additional erosion control and nutrient management practices would be expected to reduce instream nitrogen loads delivered to the Mississippi River by about 6 percent. Higher percent reductions could occur among some of the tributary subregions. The highest reduction in terms of pounds saved would occur for the Middle and Lower Platte River Basin (code 1020), where over 10 million pounds of nitrogen per year would be removed from instream loads with additional conservation treatment.

Total Phosphorus

Baseline condition. Phosphorus loads delivered to rivers and streams from all sources totaled about 71 million pounds per year (table 54). Instream phosphorus loads delivered to the Mississippi River, after accounting for instream deposition, reservoir dynamics, and other transport processes, was much lower, totaling about 55 million pounds per year, averaged over the 47 years of weather as simulated in the model (table 63).

About 32 percent of the instream phosphorus load delivered to the Mississippi River is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the “background” scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 63).

The largest contribution of instream phosphorus loads among tributary subregions is from the Middle and Lower Platte River (code 1020), with 12.0 million pounds per year, and the Lower Yellowstone River Basin (code 1010), with 8.7 million pounds per year. These two subregions also had the highest loads from background sources.

Tributary subregions with the highest percentages of instream loads attributable to cultivated cropland are: the Elkhorn River Basin (code 1022) with 81 percent; the James River Basin (code 1016) with 80 percent; and the Republican River Basin (code 1025) with 75 percent. (These same three subregions also had the highest percent of instream nitrogen loads attributable to cultivated cropland [table 63].)

The instream loads for outlets along the mainstem include phosphorus loads from upstream sources and additional loads contributed from within the subregion. In general these mainstem loads are smallest near the headwaters and largest near the outlet of the Missouri River. The presence of lakes and reservoirs along the mainstem of the river disrupt this trend, as was shown for instream sediment loads (table 63). As seen for instream nitrogen loads, instream phosphorus loads increase dramatically—almost 14 fold—over the four most downstream subregions along the mainstem, demonstrating that the bulk of phosphorus loads are coming from subregions that discharge into the lower one-third of the Missouri River.

Effects of conservation practices.
Model simulations of instream loads indicate that conservation practices have reduced the delivery of phosphorus from the Missouri River Basin to the Mississippi River by about 28 percent overall (table 63 and fig. 104). Without conservation practices, the total phosphorus delivered to the Mississippi River would be larger by 21.5 million pounds per year. Percent reductions are higher for some subregions, as shown in table 63.

The largest reduction among the tributary subregions is for the Middle and Lower Platte River Basin (code 1020), where nearly 7.5 million pounds per year of the instream phosphorus load has been reduced due to conservation practices.

Potential gains from further conservation treatment.
As was the case for sediment, the relatively low levels of phosphorus loss from farm fields throughout most of this region and the relatively large contributions of phosphorus from sources other than cultivated cropland limit the potential for reductions in instream loads from further conservation treatment, as shown in table 63 and figure 104. Treatment of the 15.3 million under-treated acres in the region with additional erosion control and nutrient management practices would be expected to reduce instream phosphorus loads delivered to the Mississippi River by about 4 percent. Higher percent reductions could occur among some of the tributary subregions.

Atrazine

Baseline condition. Atrazine loads delivered to rivers and streams from cultivated cropland totaled about 90,000 pounds per year (table 58). Instream atrazine loads delivered to the Mississippi River, after accounting for instream deposition, reservoir dynamics, and other transport processes, totaled about 61,400 pounds per year, averaged over the 47 years of weather as simulated in the model (table 64).

Effects of conservation practices.
Model simulations of instream loads indicate that conservation practices have reduced the delivery of atrazine from the Missouri River Basin to the Mississippi River by about 32 percent overall (table 64 and fig. 105). Without conservation practices, the total atrazine delivered to the Mississippi River would be larger by 28,500 pounds per year. Percent reductions range from 15 to 48 percent among the tributary subregions, as shown in table 64.

The largest reduction among the tributary subregions was for the Middle and Lower Platte River Basin (code 1020), where 8,700 pounds per year of the instream atrazine load has been reduced due to conservation practices.

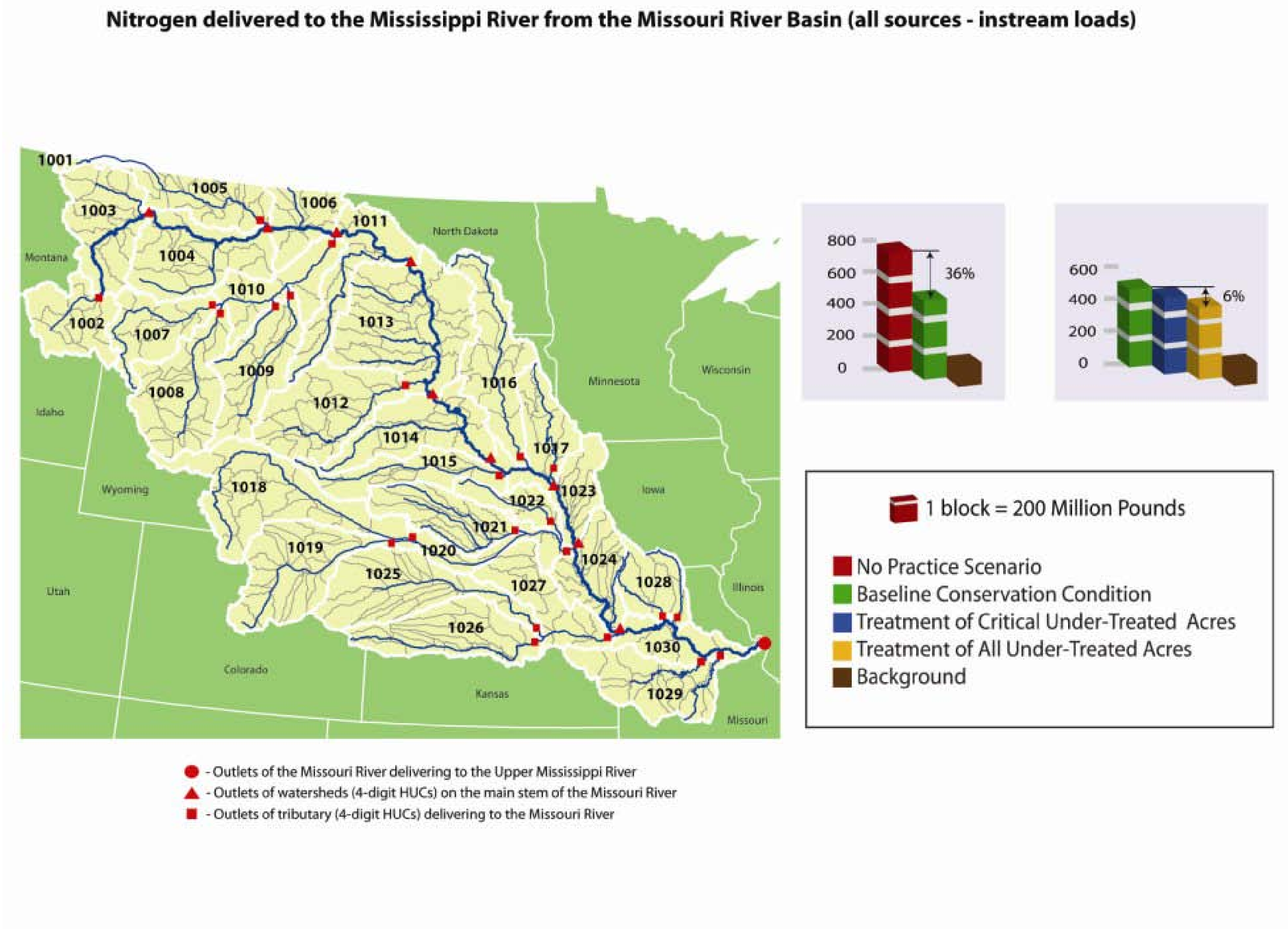
Potential gains from further conservation treatment.
The relatively low level of atrazine use throughout the Missouri River Basin limits the potential for reductions in instream loads from further conservation treatment, as shown in table 64 and figure 105. Treatment of the 15.3 million under-treated acres in the region with additional erosion control and nutrient management practices would be expected to reduce instream atrazine loads delivered to the Mississippi River by about 4 percent. An 8-percent reduction is possible in the Middle and Lower Platte River Basin (code 1020), which had the largest instream atrazine loads for the baseline conservation condition among the tributary subregions.

Table 62. Average annual ***instream nitrogen loads*** (all sources) for the baseline conservation condition, no-practice scenario, and the erosion control with nutrient management treatment scenario, Missouri River Basin

	Baseline conservation condition			No-practice scenario			Additional conservation treatment for all 15.3 million under-treated acres		
Subregions	Load from all sources (1,000 pounds)	Background sources** (1,000 pounds)	Percent of load attributed to cultivated cropland sources	Load from all sources (1,000 pounds)	Reductions due to conservation practices (1,000 pounds)	Percent reduction	Load from all sources (1,000 pounds)	Reductions from baseline due to additional conservation treatment (1,000 pounds)	Percent reduction
Tributary subregions									
Milk River Basin (code 1005)	2,147	932	57	5,904	3,757	64	1,933	214	10
Upper Yellowstone River Basin (code 1007)	15,780	12,910	18	20,650	4,870	24	14,850	930	6
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	12,404	9,015	27	15,890	3,486	22	10,158	2,246	18
Lower Yellowstone River (code 1010)	30,840	23,150	25	45,190	14,350	32	27,380	3,460	11
Cheyenne River (code 1012)	6,646	4,969	25	10,570	3,924	37	6,610	36	1
Niobrara River Basin (code 1015)	17,860	11,220	37	28,340	10,480	37	16,280	1,580	9
James River Basin (code 1016)	22,080	1,159	95	43,840	21,760	50	21,530	550	2
North Platte River Basin (code 1018)	9,852	2,553	74	17,220	7,368	43	5,747	4,105	42
South Platte River Basin (code 1019)	25,010	13,810	45	46,470	21,460	46	21,110	3,900	16
Middle and Lower Platte River Basin (code 1020)	97,000	34,190	65	157,500	60,500	38	86,680	10,320	11
Loup River Basin (code 1021)	26,330	14,460	45	41,390	15,060	36	25,270	1,060	4
Elkhorn River Basin (code 1022)	33,490	7,029	79	52,020	18,530	36	28,480	5,010	15
Republican River Basin (code 1025)	9,502	961	90	18,820	9,318	50	9,323	179	2
Smoky Hill River Basin (code 1026)	9,455	2,295	76	18,670	9,215	49	9,432	23	0
Kansas-Big Blue River Basin (code 1027)	30,470	10,080	67	51,740	21,270	41	29,300	1,170	4
Chariton-Grand River Basin (code 1028)	25,090	9,356	63	49,520	24,430	49	22,810	2,280	9
Gasconade-Osage River Basin (code 1029)	18,470	10,130	45	22,990	4,520	20	18,360	110	1
Outlets along mainstem									
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	20,309	10,052	39	42,228	21,919	52	19,793	516	3
Missouri-Musselshell-Fort Peck Lake (code 1004)	5,462	2,755	50	8,938	3,476	39	5,462	0	0
Missouri-Poplar River Basin (code 1006)	13,550	4,634	66	43,930	30,380	69	13,230	320	2
Missouri-Little Missouri-Lake Sakakawea (code 1011)	22,090	14,050	36	46,920	24,830	53	20,870	1,220	6
Missouri-Grand-Moreau-Lake Oahe (code 1013)	15,300	8,634	44	34,950	19,650	56	14,350	950	6
Missouri-White River -Fort Randall Reservoir (code 1014)	13,350	8,140	39	26,870	13,520	50	12,860	490	4
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	54,230	17,570	68	88,700	34,470	39	51,950	2,280	4
Missouri-Little Sioux River Basin (code 1023)	117,900	31,300	73	182,300	64,400	35	112,300	5,600	5
Missouri-Nishnabotna River Basin (code 1024)	388,100	109,500	72	615,600	227,500	37	364,700	23,400	6
Load delivered to the Mississippi River (code 1030)	511,300	167,700	67	792,800	281,500	36	482,100	29,200	6

** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 103. Effects of conservation practices on average annual instream nitrogen loads, Missouri River Basin



Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

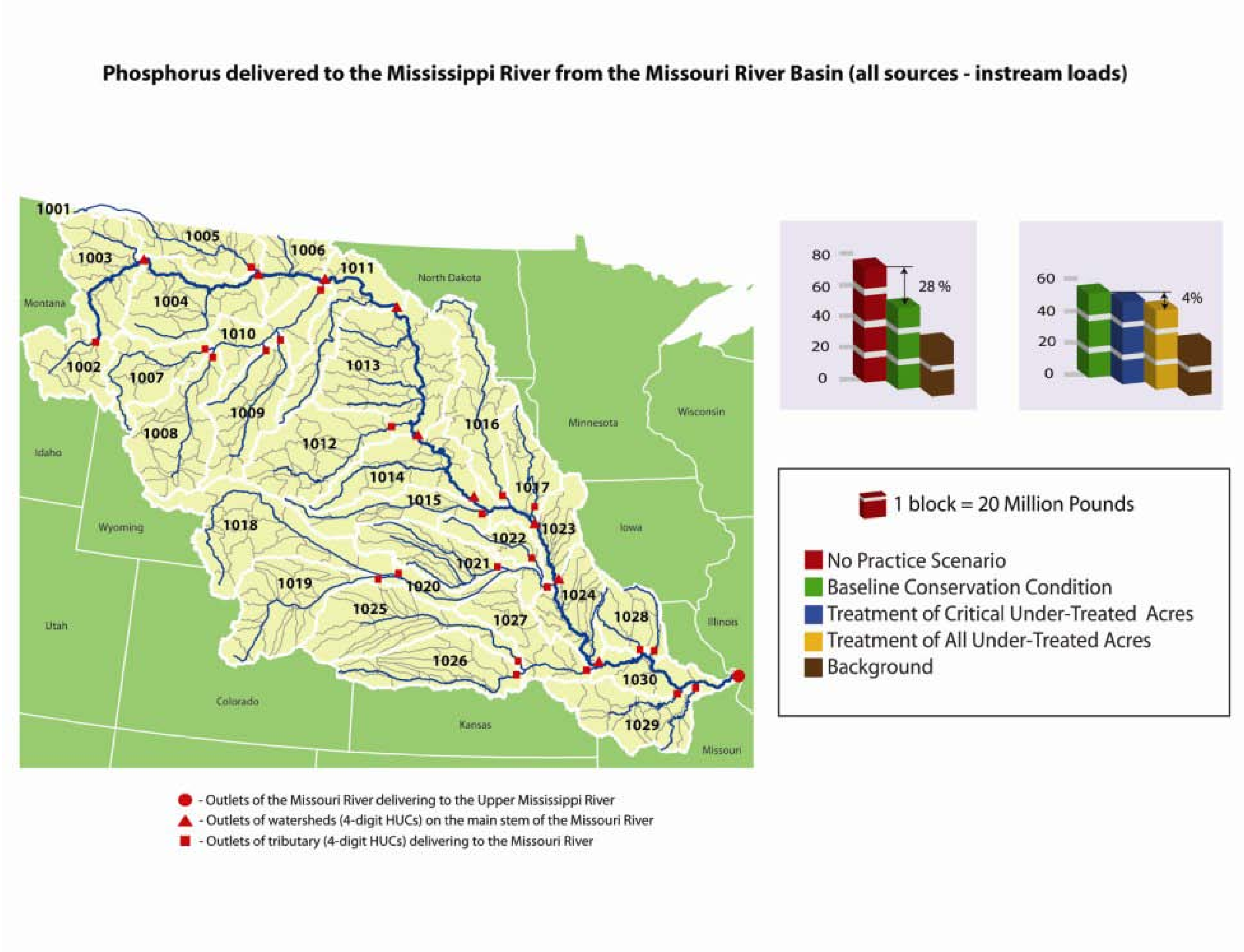
Table 63. Average annual ***instream phosphorus loads*** (all sources) for the baseline conservation condition, no-practice scenario, and the erosion control with nutrient management treatment scenario, Missouri River Basin

	Baseline conservation condition			No-practice scenario			Additional conservation treatment for all 15.3 million under-treated acres		
Subregions	Load from all sources (1,000 pounds)	Background sources** (1,000 pounds)	Percent of load attributed to cultivated cropland sources	Load from all sources (1,000 pounds)	Reductions due to conservation practices (1,000 pounds)	Percent reduction	Load from all sources (1,000 pounds)	Reductions from baseline due to additional conservation treatment (1,000 pounds)	Percent reduction
Tributary subregions									
Milk River Basin (code 1005)	184	89	52	329	145	44	169	15	8
Upper Yellowstone River Basin (code 1007)	1,509	1,258	17	1,727	218	13	1,407	102	7
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)	5,156	4,994	3	5,303	147	3	5,051	105	2
Lower Yellowstone River (code 1010)	8,685	8,009	8	9,368	683	7	8,333	352	4
Cheyenne River (code 1012)	514	447	13	627	113	18	514	0	0
Niobrara River Basin (code 1015)	404	305	25	573	169	29	399	5	1
James River Basin (code 1016)	853	170	80	1,446	593	41	853	0	0
North Platte River Basin (code 1018)	701	386	45	1,567	866	55	501	200	29
South Platte River Basin (code 1019)	6,011	5,616	7	7,693	1,682	22	5,837	174	3
Middle and Lower Platte River Basin (code 1020)	12,040	8,269	31	19,530	7,490	38	11,410	630	5
Loup River Basin (code 1021)	594	200	66	1,642	1,048	64	589	5	1
Elkhorn River Basin (code 1022)	1,550	290	81	3,101	1,551	50	1,459	91	6
Republican River Basin (code 1025)	651	165	75	1,433	782	55	643	8	1
Smoky Hill River Basin (code 1026)	762	329	57	1,065	303	28	757	6	1
Kansas-Big Blue River Basin (code 1027)	5,113	3,218	37	7,891	2,778	35	4,935	178	3
Chariton-Grand River Basin (code 1028)	4,404	2,764	37	8,324	3,920	47	4,088	316	7
Gasconade-Osage River Basin (code 1029)	2,794	2,364	15	3,282	488	15	2,780	14	1
Outlets along mainstem									
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)	1,921	1,120	37	2,731	810	30	1,865	56	3
Missouri-Musselshell-Fort Peck Lake (code 1004)	2,275	1,153	49	3,222	947	29	2,166	109	5
Missouri-Poplar River Basin (code 1006)	2,762	1,243	55	4,234	1,472	35	2,655	107	4
Missouri-Little Missouri-Lake Sakakawea (code 1011)	3,012	2,697	10	3,477	465	13	3,001	11	0
Missouri-Grand-Moreau-Lake Oahe (code 1013)	4,582	3,373	26	5,816	1,234	21	4,510	72	2
Missouri-White River -Fort Randall Reservoir (code 1014)	2,290	1,876	18	2,809	519	18	2,265	25	1
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)	3,924	2,593	34	5,582	1,658	30	3,913	11	0
Missouri-Little Sioux River Basin (code 1023)	13,630	9,056	34	17,740	4,110	23	13,270	360	3
Missouri-Nishnabotna River Basin (code 1024)	35,430	22,180	37	53,380	17,950	34	33,600	1,830	5
Load delivered to the Mississippi River (code 1030)	54,650	37,180	32	76,100	21,450	28	52,540	2,110	4

****** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 104. Effects of conservation practices on average annual instream phosphorus loads, Missouri River Basin



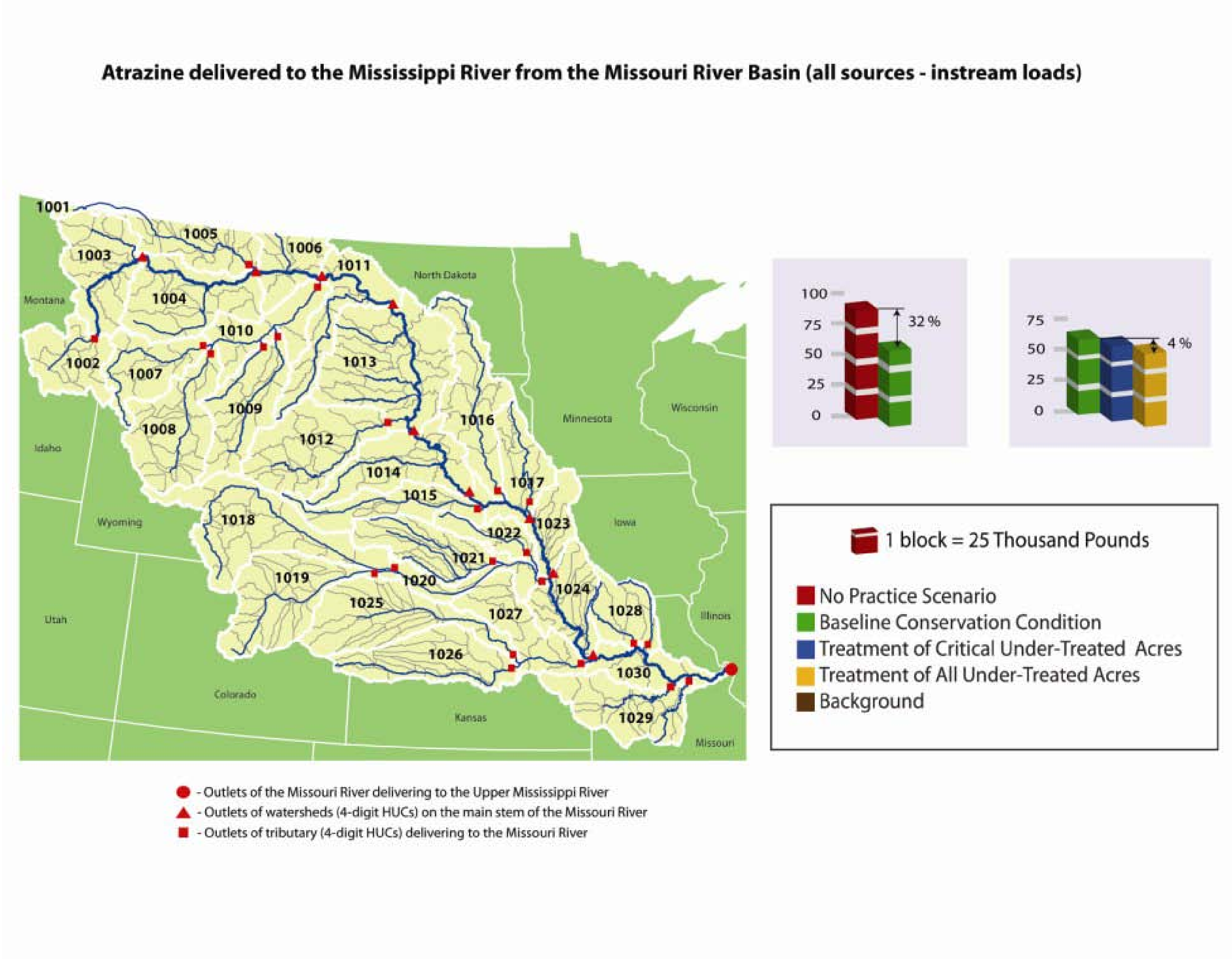
Note: “Background sources” represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. “Background” loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Table 64. Average annual ***instream atrazine loads*** for the baseline conservation condition, no-practice scenario, and the erosion control with nutrient management treatment scenario, Missouri River Basin*

Subregions	Baseline conservation condition	No-practice scenario			Additional conservation treatment for all 15.3 million under-treated acres		
	Load from cultivated cropland (1,000 pounds)	Load from cultivated cropland (1,000 pounds)	Reductions due to conservation practices (1,000 pounds)	Percent reduction	Load from cultivated cropland (1,000 pounds)	Reductions from baseline due to additional conservation treatment (1,000 pounds)	Percent reduction
Tributary subregions							
Middle and Lower Platte River Basin (code 1020)	10.7	19.5	8.7	45	9.9	0.8	8
Loup River Basin (code 1021)	2.6	4.9	2.3	47	2.5	0.1	3
Elkhorn River Basin (code 1022)	2.2	4.2	2.0	48	2.1	0.1	4
Kansas-Big Blue River Basin (code 1027)	8.0	11.7	3.7	32	7.8	0.2	2
Chariton-Grand River Basin (code 1028)	6.7	12.2	5.5	45	6.4	0.2	4
Gasconade-Osage River Basin (code 1029)	3.0	3.5	0.5	15	3.0	0.0	0
Outlets along mainstem							
Missouri-Little Sioux River Basin (code 1023)	7.0	11.5	4.4	39	7.0	0.0	0
Missouri-Nishnabotna River Basin (code 1024)	33.9	51.5	17.6	34	31.9	2.0	6
Load delivered to the Mississippi River (code 1030)	61.4	90.0	28.5	32	58.9	2.5	4

***** Only subregions with significant atrazine use are shown.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 105. Effects of conservation practices on average annual instream atrazine loads, Missouri River Basin



Note: Cultivated cropland is the only source of atrazine included in the modeling; consequently, “background sources” are zero for atrazine.

Chapter 8
Summary of Findings

Field Level Assessment

The Baseline Conservation Condition
The baseline conservation condition represents model simulations of erosion, changes in soil organic carbon, and losses from farm fields of nitrogen, phosphorus, and pesticides through various loss pathways. Wind erosion accounts for most of the soil and nutrient losses from farm fields in this region. While conservation practices in use during 2003–06 have been effective in reducing wind erosion, model simulations show that rates can exceed 4 tons per acre in at least some years for 12 percent of the acres in the region, and exceed 2 tons per acre in some years for about 20 percent of the acres. About 60 percent of total phosphorus lost from fields and 25 percent of total nitrogen is with windborne sediment. Wind erosion is much higher in the western portion of the basin, averaging 1.64 tons per acre per year. About 85 percent of total phosphorus and 35 percent of total nitrogen in this portion of the basin are lost from farm fields with windborne sediment. Wind erosion in the eastern portion of the region averages 0.46 ton per acre, which is still high enough to be of concern in some years; 35 percent of total phosphorus and 15 percent of total nitrogen in this portion of the basin are lost from farm fields with windborne sediment.

Losses of sediment, nutrients, and pesticides with water are also important for some acres in the region, especially in the eastern portion of the basin.

Evaluation of Practices in Use
The first Federal conservation efforts on cropland were focused primarily on water management and soil erosion control. Structural practices such as waterways, terraces, and diversions were installed along with supporting practices such as contour farming and stripcropping. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres—highly erodible land. This legislation created the Conservation Reserve Program as a mechanism for establishing long-term conserving cover on the most erodible cropland through multi-year contracts with landowners. More recently, the focus has shifted from soil conservation and sustainability to a broader goal of reducing all pollution impacts associated with agricultural production. Prominent among new concerns are the environmental effects of nutrient and pesticide export from farm fields.

Given the long history of conservation in the Missouri River Basin, it is not surprising to find that nearly all cropped acres in the region have evidence of some kind of conservation practice, especially erosion control practices. The conservation practice information collected during the study was used to assess the extent of conservation practice use. Key findings are the following.

- Structural practices for controlling water erosion are in use on 41 percent of cropped acres. On the 40 percent of cropped acres designated as highly erodible land, structural practices designed to control water erosion are in use on 49 percent of those acres. Structural practice use is more prevalent in the eastern portion of the basin, where 48 percent of cropped acres, including 73 percent of highly erodible land, have one or more structural conservation practice in use.
- Reduced tillage is common in the region; 93 percent of the cropped acres meet criteria for either no-till (46 percent) or mulch till (47 percent). All but 3 percent of the acres had evidence of some kind of reduced tillage on at least one crop.
- About 60 percent of cropped acres are gaining soil organic carbon, including 84 percent of cropped acres in the eastern portion of the region and 42 percent in the western portion.
- Producers use either residue and tillage management practices or structural practices, or both, on 98 percent of the acres.
- Nutrient management practices are widely used on cropped acres in the Missouri River Basin.
  - 72 percent of cropped acres meet criteria for timing of nitrogen applications on all crops and 75 percent of cropped acres meet criteria for timing of phosphorus applications on all crops.
  - 61 percent of cropped acres meet criteria for method of nitrogen application on all crops and 70 percent meet criteria for method of phosphorus application on all crops.
  - 62 percent of cropped acres meet criteria for nitrogen application rate on all crops and 41 percent meet criteria for phosphorus application rates for the full crop rotation.
- Although most cropped acres meet nutrient management criteria for rate, timing, or method, fewer acres meet criteria for all three:
  - 35 percent of cropped acres meet all criteria for nitrogen applications, including 43 percent of cropped acres in the western portion of the basin;
  - 41 percent of cropped acres meet all criteria for phosphorus applications, including 45 percent of cropped acres in the eastern portion of the basin; and
  - 24 percent of cropped acres meet criteria for *both* phosphorus and nitrogen, including 27 percent of cropped acres in the western portion of the basin.
- During the 2003–06 period of data collection cover crops were used on less than 1 percent of the acres in the region.
- An Integrated Pest Management (IPM) indicator showed that only about 7 percent of the acres were being managed at a relatively high level of IPM.
- Land in long-term conserving cover, as represented by enrollment in the Conservation Reserve Program (CRP) General Signup, consists of about 11.2 million acres in the region, of which 72 percent is highly erodible land.

Effects of Conservation Practices

Model simulation results show that, for cropped acres in the region, *on average* conservation practices have—

- Reduced surface water runoff in the region by about 0.4 inch per year averaged over all acres, representing a 25-percent reduction;
- Reduced surface water runoff by 2.1 inches per year, on average, for irrigated acres and 0.2 inch per year for non-irrigated acres;
- Increased the volume of subsurface flows by an average of 0.4 inch per year, with higher increases in the eastern portion of the basin and lower increases in the western portion.
- Reduced wind erosion by 2.04 tons per acre in the western portion of the basin and 0.88 ton per acre in the eastern portion, representing a 58 percent reduction for the entire region;
- Reduced average sediment loss from water erosion in the eastern portion of the basin by an average of 1.26 tons per acre per year, representing a 72-percent reduction, and by an average of 0.3 ton per acre per year in the western portion of the basin, representing a 79-percent reduction;
- Resulted in an average gain in soil organic carbon of 65 pounds per acre per year, with higher gains in the eastern portion of the basin;
- Reduced total nitrogen loss (volatilization, denitrification, windborne sediment, surface runoff, and subsurface flow losses) by an average of 15 pounds per acre per year, representing a 39-percent reduction;
    - Reduced nitrogen lost with windborne sediment in the western portion of the basin by an average of 6 pounds per acre per year, representing an average reduction of 46 percent, and by 3.6 pounds per acre per year in the eastern portion, representing a 47-percent reduction.
    - Reduced nitrogen loss in subsurface flows by an average of 8.0 pounds per acre (60-percent reduction) in the western portion of the basin and by an average of 2.4 pounds per acre in the eastern portion (21-percent reduction);
    - Reduced nitrogen lost with surface runoff by 6.2 pounds per acre per year in the eastern portion of the basin, representing a 56-percent reduction, and reduced nitrogen lost with surface runoff in the western portion by 1.6 pounds per acre, representing a 66-percent reduction;
- Reduced total phosphorus loss by an average of 2.4 pounds per acre per year, representing a 58-percent reduction;
    - Reduced phosphorus lost with windborne sediment in the western portion of the basin by an average of 1.57 pounds per acre per year, representing an average reduction of 55 percent, and by an average of 1.23 pounds per acre per year in the eastern portion, representing an average reduction of 63 percent;
    - Reduced phosphorus lost to surface water in the eastern portion of the basin by an average of 1.76 pounds per acre per year, representing an average reduction of 58 percent, and by an average of 0.38 pound per acre per year in the western portion, representing an average reduction of 63 percent; and
- Reduced pesticide loss from fields to surface water by 46 percent, resulting in:
    - a 64-percent reduction in the edge-of-field surface water pesticide risk indicator (all pesticides combined) for aquatic ecosystems;
    - a 45-percent reduction in the edge-of-field surface water pesticide risk indicator for humans, and
    - a 23-percent reduction in the edge-of-field groundwater pesticide risk indicator for humans.

Use of improved irrigation systems in the Missouri River Basin increases irrigation efficiency from 50 percent in the no-practice scenario to 69 percent in the baseline scenario. This change in efficiency represents an annual decreased need for irrigation water of 6 inches per year where irrigation is used.

At 11.2 million acres, land in long-term conserving cover is an important part of the agricultural landscape in the Missouri River Basin. The benefits of this conservation “practice” were estimated by simulating crop production on these acres without use of conservation practices. Model simulation results show that soil erosion and sediment loss have been almost completely eliminated for land in long-term conserving cover. Compared to a cropped condition without conservation practices, total nitrogen loss has been reduced by 81 percent, total phosphorus loss has been reduced by 99 percent, and soil organic carbon has been increased by an average of 192 pounds per acre per year.

Conservation Treatment Needs

The adequacy of conservation practices in use in the Missouri River Basin for the time period 2003–06 was evaluated to identify conservation treatment needs for five resource concerns:

- wind erosion,
- sediment loss with water erosion,
- nitrogen lost with surface runoff (attached to sediment and in solution),
- nitrogen loss in subsurface flows, and
- phosphorus lost to surface water (includes soluble phosphorus in lateral flow, soluble phosphorus in surface water runoff, and phosphorus lost with waterborne sediment).

Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres to reduce field-level losses to acceptable levels. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Under-treated acres were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Three levels of treatment need were identified:

- Acres with a "high" level of need for conservation treatment consist of the most critical under-treated acres in the region. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients.
- Acres with a "moderate" level of need for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability and/or have more conservation practice use than acres with a high level of need. The treatment level required is not necessarily less, although it can be, but rather the sediment and nutrient losses are lower and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment.
- Acres with a "low" level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. While gains can be obtained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

Findings for the Missouri River Basin indicate that—

- 1 percent of cropped acres (1.1 million acres) have a **high** level of need for additional conservation treatment,
- 17 percent of cropped acres (14.2 million acres) have a **moderate** level of need for additional conservation treatment, and
- 82 percent of cropped acres (68.3 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.

About 70 percent of the under-treated acres (acres with a "high" or "moderate" need for additional treatment) are in the western portion of the region.

The 1.1 million acres with a "high" level of need for conservation treatment lose (per acre per year, on average): 3.1 tons of sediment by water erosion; 8.0 pounds of phosphorus; and 58 pounds of nitrogen. Wind erosion averages 2.0 tons per acre per year for these acres.

The 14.2 million acres with a "moderate" level of need for conservation treatment lose (per acre per year, on average): 0.4 ton of sediment by water erosion; 2.6 pounds of phosphorus; and 30 pounds of nitrogen. Wind erosion averages 2.9 tons per acre per year for these acres.

Losses for the 68.3 million acres with a "low" level of need are small on a per-acre basis. These acres lose (per acre per year, on average): 0.2 ton of sediment by water erosion; 1.4 pounds of phosphorus; and 21 pounds of nitrogen. Wind erosion averages 0.7 ton per acre per year for these acres.

The most pervasive concern in the region is excessive rates of wind erosion during dry periods, including windborne losses of nitrogen and phosphorus. The proportion of cropped acres with a "high" or "moderate" need for additional conservation treatment by resource concern was determined to be—

- 12.4 percent for wind erosion (less than 0.1 percent with a high need for treatment),
- 3.4 percent for sediment loss (0.4 percent with a high need for treatment),
- 3.9 percent for nitrogen loss with surface runoff (0.5 percent with a high need for treatment),
- 0.9 percent for phosphorus lost to surface water (0.4 percent with a high need for treatment), and
- 2.2 percent for nitrogen loss in subsurface flows (0.3 percent with a high need for treatment), most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Most of the under-treated acres for wind erosion and nitrogen loss in subsurface flows are in the western portion of the basin. Most of the under-treated acres for resource concerns associated with water runoff are in the eastern portion of the basin.

Nearly 80 percent of the under-treated acres are under-treated for only one of the five resource concerns:

- 62 percent of under-treated acres are under-treated only for wind erosion,
- 7 percent of under-treated acres are under-treated only for nitrogen leaching,
- 6 percent of under-treated acres are under-treated only for nitrogen runoff, and
- about 3 percent of under-treated acres are under-treated for sediment loss only.

One-fourth of under-treated acres need additional treatment for the three resource concerns related to runoff. Another 10 percent need treatment for nitrogen leaching <u>and</u> phosphorus runoff. Only about 7 percent of under-treated acres were determined to be under-treated for all four resource concerns.

Under-treated acres in the Missouri River Basin are distributed throughout all of the subregions, but are the most concentrated in five subregions—the North Platte River Basin (code 1018), the Big Horn and Powder-Tongue River Basins (codes 1008, 1009), the Lower Yellowstone River (code 1010), and the South Platte River Basin (code 1019). These five subregions include 7 percent of the cropped acres in the region but have 23 percent of the under-treated acres in the region. Ten other subregions have less pronounced disproportionately high percentages of under-treated acres, accounting for 33 percent of the cropped acres in the region and 47 percent of the under-treated acres.

In contrast, 14 subregions have disproportionately low percentages of under-treated acres relative to cropped acres These 14 subregions include 60 percent of the cropped acres in the region but have only 30 percent of the under-treated acres in the region.

Simulation of Additional Conservation Treatment

Model simulations were used to evaluate the potential gains from further conservation treatment in the Missouri River Basin.

Three sets of additional conservation practices were simulated:

1. Additional wind and water erosion control practices consisting of four types of structural practices—overland flow practices, concentrated flow practices, edge-of-field mitigation—and wind erosion control practices.
2. Application of nitrogen and phosphorus using appropriate rate, timing, and method.
3. Increases in the efficiency of irrigation water application.

Model simulation was used to estimate the gains that could be attained when soil erosion control practices, nutrient management practices, and increased irrigation efficiencies are applied in this region:

- Conservation treatment of the 1.1 million acres with a high need for treatment would reduce sediment loss by an average of 2.9 tons per acre per year on those acres. In comparison, additional treatment of the 14.2 million acres with a moderate need for treatment would reduce sediment loss by about 0.3 ton per acre per year on those acres. Treatment of the remaining 68.3 million acres would reduce sediment loss on those acres by less than 0.2 ton per acre, on average.
- Total nitrogen loss would be reduced by an average of 31.4 pounds per acre per year on the 1.1 million acres with a high need for treatment, compared to a reduction of 12.2 pounds per acre for the 14.2 million under-treated acres with a moderate need for treatment, and only 5.8 pounds per acre for the remaining 68.3 million acres.
- Nitrogen loss in subsurface flows would be reduced by an average of 11 pounds per acre per year on the 1.1 million acres with a high need for treatment, compared to a reduction of 3.9 pounds per acre for the 14.2 million acres with a moderate need for treatment. The reduction for treatment of the remaining 68.3 million acres would average only 1.7 pounds per acre.
- Total phosphorus loss would be reduced by an average of 4.9 pounds per acre per year on the 1.1 million critical under-treated acres, compared to a reduction of 1.4 pounds per acre for the 14.2 million under-treated acres with a moderate need for treatment and only 0.6 pound per acre for the remaining 68.3 million acres.

Compared to the baseline conservation condition, treating the 15.3 million under-treated acres (18 percent of cropped acres in the region) would, for the region as a whole—

- reduce sediment loss averaged over all cropped acres in the region by 37 percent;
- reduce wind erosion averaged over all cropped acres in the region by 22 percent,
- reduce total nitrogen loss averaged over all cropped acres in the region by 11 percent:
    - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) averaged over all cropped acres in the region by 24 percent, and
    - reduce nitrogen loss in subsurface flows averaged over all cropped acres in the region by 12 percent;
- reduce phosphorus lost to surface water averaged over all cropped acres in the region by 20 percent; and
- reduce environmental risk from loss of pesticide residues averaged over all cropped acres in the region by 4 to 7 percent.

The bulk of the potential field-level savings from conservation treatment, relative to losses simulated for the no-practice scenario, have been achieved in this region. The percent of potential savings represented by practices in use in 2003–06 are: 75 percent for sediment, 68 percent for nitrogen, and 76 percent for phosphorus. By treating all 15.3 million under-treated acres in the region with additional erosion control and nutrient management practices, an additional 10 percent in savings would be attained for sediment, 11 percent for nitrogen, and 9 percent for phosphorus. To achieve 100 percent of potential savings (i.e., an additional 15 percent for sediment and phosphorus and 21 percent for nitrogen), additional conservation treatment for the remaining 68.3 million acres with a low need for additional treatment would be required, which would result in very small conservation gains on a per-acre basis.

Conservation Practice Effects on Water Quality

Reductions in field-level losses due to conservation practices, including land in long-term conserving cover, translate into improvements in water quality in streams and rivers in the region. Transport of sediment, nutrients, and pesticides from farm fields to streams and rivers involves a variety of processes and time-lags, and not all of the potential pollutants leaving fields contribute to instream loads.

Cultivated cropland represents about 30 percent of the land base in the Missouri River Basin. At the 2003–06 level of conservation practice use, cultivated cropland delivered a disproportionate amount of sediment and nutrients to rivers and streams and ultimately to the Mississippi River. Of the total loads delivered to rivers and streams from all sources, cultivated cropland is the source for 72 percent of the sediment, 68 percent of the nitrogen, and 46 percent of the phosphorus.

For the baseline conservation condition, sediment, nutrient, and atrazine loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, are—

- 14.0 million tons of sediment (72 percent of loads from all sources);
- 500 million pounds of nitrogen (68 percent of loads from all sources);
- 33 million pounds of phosphorus (46 percent of loads from all sources); and
- 90,000 pounds of atrazine.

Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced sediment, nutrient, and atrazine loads **delivered to**

rivers and streams from cultivated cropland sources per year, on average, by —

- 76 percent for sediment;
- 54 percent for nitrogen;
- 60 percent for phosphorus, and
- 36 percent for atrazine.

Model simulations further showed that if all of the under-treated acres (15.3 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads **delivered to rivers and streams from cultivated cropland sources** in the region would be reduced, relative to the baseline conservation condition, by—

- 28 percent for sediment,
- 13 percent for nitrogen,
- 12 percent for phosphorus, and
- 5 percent for atrazine.

Instream loads are estimated by starting with the loads delivered from all sources at the outlet of each 8-digit HUC and routing those loads downstream. Stream and channel processes are simulated, including flood routing, instream degradation processes, streambed deposition, streambank erosion, and reservoir dynamics. A portion of the sediment, nutrients, and pesticides delivered to rivers and streams are removed or trapped during these processes. Some of the nitrogen is lost during instream nitrification processes, and a portion of the sediment and sediment-bound nutrients and pesticides are deposited in streambeds and flood plains during transit. Large reservoirs can trap significant amounts of loads delivered to rivers and streams, keeping those loads from being transferred downstream. Sediment can also be added to instream loads through streambank erosion and streambed scouring.

Model simulations showed that instream **loads from all sources delivered from the region to the Mississippi River** per year, on average, are:

- 44 million tons of sediment (22 percent attributable to cultivated cropland sources);
- 511 million pounds of nitrogen (67 percent attributable to cultivated cropland sources);
- 55 million pounds of phosphorus (32 percent attributable to cultivated cropland sources); and
- 61,000 pounds of atrazine;

Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced **instream loads from all sources delivered from the region to the Mississippi River** per year, on average, by:

- 4 percent for sediment;
- 36 percent for nitrogen;
- 28 percent for phosphorus, and
- 32 percent for atrazine.

Additional conservation treatment of the 15.3 million under-treated acres in the region would be expected to further reduce **instream loads from all sources delivered from the region to the Mississippi River** per year relative to the baseline, on average, by:

- 1 percent for sediment;
- 6 percent for nitrogen;
- 4 percent for phosphorus, and
- 4 percent for atrazine.

Comparison of Findings to Other Regions

Because of the relatively low annual precipitation in this region and the widespread use of soil erosion control practices, nutrient management practices, and increased irrigation efficiencies, the per-acre losses at the field level throughout most of this region are lower than in other regions, with the important exception of wind erosion. Tables 65 through 68 compare CEAP findings for three water resource regions—the Missouri River Basin, the Upper Mississippi River Basin, and the Ohio-Tennessee River Basin—which together make up the northern part of the Mississippi River drainage system.

The Missouri River Basin is the largest water resource region within the Mississippi River drainage system. It includes about the same amount of cultivated cropland as found in the Upper Mississippi River Basin and the Ohio-Tennessee River Basin combined (table 65). Nevertheless, grazing land (pasture and rangeland) is the dominant land cover in the Missouri River Basin.

Cropping systems in the eastern portion of the basin are similar to those in the Upper Mississippi River and Ohio-Tennessee River basins, dominated by corn and soybean rotations. The western portion of the basin, however, is dominated by wheat and other close-grown crops. Irrigation is much more common and manure application on cropped acres is less common in the Missouri River basin than in the other two water resource regions.

Vulnerability factors are generally similar among the three water resource regions, with the important exceptions of annual precipitation and the potential for wind erosion (table 65). Average annual precipitation in the Missouri River Basin is 11 inches per year less than in the Upper Mississippi River Basin and about half of the amount in the Ohio-Tennessee River basin. Because of the low precipitation, soils are prone to wind erosion in the Missouri River basin, whereas wind erosion is not a resource concern most of the time in the other two regions.

Table 65. Comparison of land use, vulnerability, and conservation practice use among three of the five water resource regions that make up the Mississippi River drainage system

	Missouri River Basin			Upper Mississippi River Basin (revised)*	Ohio-Tennessee River Basin
	Western portion	Eastern portion	Entire basin		
Total acres in basin (million acres excluding water)	244.4	77.8	322.2	118.2	128.5
Total acres of cultivated cropland (million acres)	56.3	38.8	95.1	63.5	26.8
Land use (percent of total acres excluding water)					
Cultivated cropland	23	50	30	54	21
Hayland	1	7	3	5	6
Pasture and rangeland	63	23	53	7	12
Urban land	2	6	3	8	9
Forest and other	11	13	11	26	52
Cultivated cropland (percent of cropped acres)					
Crop rotations with corn and soybean only	6	67	32	74	69
Crop rotations with wheat or other close-grown crops only	51	1	30	<1	<1
Crop rotations with hay and other crops	7	3	5	6	4
Irrigated	17	11	14	2	1
Manure applied	3	8	5	16	9
Vulnerability factors					
Average annual precipitation (inches)	18	29	23	34	42
Slopes greater than 2% (percent of cropped acres)	48	49	48	42	33
Highly Erodible Land (percent of cropped acres)	46	32	40	18	27
High soil runoff potential (percent of cropped acres)	7	18	12	13	9
High or moderately high soil leaching potential (percent of cropped acres)	17	3	11	10	8
High or moderately high soil wind erosion potential (percent of cropped acres)	44	6	28	1	0
Conservation practice use					
No-till (percent of cropped acres)	45	48	46	28	52
Mulch till (percent of cropped acres)	45	48	47	63	41
Structural practices for water erosion control (percent of cropped acres)	36	48	41	45	40
Structural practices for wind erosion control (percent of cropped acres)	13	7	10	3	2
High tillage and residue management level (percent of cropped acres)	33	76	52	63	59
High or moderately high nitrogen management level (percent of cropped acres)	68	62	65	41	42
High or moderately high phosphorus management level (percent of cropped acres)	59	69	63	54	43
Land in long-term conserving cover (acres enrolled in CRP General Sign-Up) as a percent of cultivated cropland acres	13	10	12	5	4

* Final estimates, revised December, 2010.

Soil erosion control practices are about equally represented among the three regions, except that a higher proportion of cropped acres in the Missouri River basin have structural practices designed to mitigate wind erosion (table 65). No-till or mulch till are in widespread use (greater than 90 percent of cropped acres) in all three regions.

Nutrient management practices are more prevalent in the Missouri River basin than in the other two regions, with more than 60 percent of the acres meeting criteria for high or moderately high nitrogen or phosphorus management (table 65).

The proportion of cultivated cropland in long-term conserving cover (CRP General Signup) in the Missouri River Basin is over twice that in the other two regions, significantly contributing to lower sediment and nutrient loads delivered to rivers and streams from cultivated cropland in this region.

Model simulations for cropped acres show that wind erosion and losses of nitrogen and phosphorus with windborne sediment are much higher in the Missouri River Basin than in the other two regions (table 66). Field-level losses of sediment and nutrients through other loss pathways, however, are much lower in the Missouri River basin.

In terms of percent reductions, practices in use in 2003–06 were more effective in reducing sediment and nutrient losses in the Missouri River basin, than in the other two (table 66). For example, total nitrogen loss (all loss pathways) has been reduced by 39 percent by conservation practices in the Missouri River Basin, compared to only 20 percent in the Upper Mississippi River Basin and 17 percent in the Ohio-Tennessee River Basin. Percent reductions for wind erosion and windborne nitrogen and phosphorus due to conservation practices are about the same in all three regions, but the magnitude of the reduction is much larger in the Missouri River Basin.

Table 66. Comparison of field level losses and the effects of conservation practices among three of the five water resource regions that make up the Mississippi River drainage system

	Missouri River Basin			Upper Mississippi River Basin (revised)*	Ohio-Tennessee River Basin
	Western portion	Eastern portion	Entire basin		
Average annual change in soil organic carbon, baseline conservation condition	-15	139	52	71	27
Average annual wind erosion and edge-of-field sediment and nutrient loss, baseline conservation condition					
Wind erosion (tons/acre)	1.64	0.46	1.13	0.23	0.02
Sediment loss (tons/acre)	0.08	0.50	0.26	0.89	1.59
Total nitrogen loss (pounds/acre)	20.4	27.3	23.4	39.0	42.6
Nitrogen lost with windborne sediment (pounds/acre)	7.1	4.1	5.8	2.1	0.2
Nitrogen loss with surface runoff (pounds/acre)	0.8	4.8	2.6	8.8	13.2
Nitrogen loss in subsurface flows (pounds/acre)	5.4	9.0	6.9	18.7	19.2
Total phosphorus loss (pounds/acre)	1.5	2.0	1.7	3.2	4.6
Phosphorus lost with windborne sediment (pounds/acre)	1.3	0.7	1.0	0.4	0.0
Phosphorus lost to surface water, sediment attached and soluble (pounds/acre)	0.2	1.3	0.7	2.7	4.5
Percent reduction in average annual wind erosion and edge-of-field sediment and nutrient loss due to conservation practice use (2003–06)					
Wind erosion	55	66	58	55	60
Sediment loss	79	72	73	61	52
Total nitrogen loss	46	31	39	20	17
Nitrogen lost with windborne sediment	46	47	46	37	47
Nitrogen loss with surface runoff	66	56	58	45	35
Nitrogen loss in subsurface flows	60	21	45	9	11
Total phosphorus loss (	57	60	58	44	33
Phosphorus lost with windborne sediment	55	63	58	55	63
Phosphorus lost to surface water, sediment attached and soluble	63	58	59	42	33

* Final estimates, revised December, 2010.

As a consequence of the lower precipitation, lower edge-of-field losses other than wind erosion, and higher level of conservation practice effectiveness, conservation treatment needs in the Missouri River Basin are proportionately lower than those in the either the Upper Mississippi River Basin or in the Ohio-Tennessee River Basin (table 67). Only 1 percent of cropped acres in the Missouri River Basin have a high need for additional conservation treatment, compared to 15 percent for the Upper Mississippi River Basin and 24 percent for the Ohio-Tennessee River Basin. Only 17 percent of cropped acres in the Missouri River Basin have a moderate need for additional conservation treatment, compared to 45 percent for the Upper Mississippi River Basin and 46 percent for the Ohio-Tennessee River Basin.

Even though the percentage of cropped acres needing additional conservation treatment is lower in the Missouri River Basin than in the other two regions, the total number of under-treated acres is high. There are 15.3 million cropped acres in the Missouri River Basin (18 percent) that have either a high or moderate need for additional conservation treatment, which is only slightly fewer than the 17.5 million under-treated acres in the Ohio-Tennessee River Basin (70 percent) (table 67).

The lower percentage of cropped acres that need additional treatment in the Missouri River Basin indicates, however, that targeting is especially important in this region for cost-effective implementation of conservation programs. Treating the 68.3 million acres that have a low need for additional treatment would provide very small per-acre reductions in field-level loss and would not be a very efficient way to reduce loads delivered to rivers and streams. But for the 15.3 million under-treated acres that do need additional treatment, significant per-acre reductions can be attained. Finding and treating the 15.3 million acres that need treatment the most is the main conservation challenge for this region.

Most under-treated acres in the Missouri River Basin need additional treatment for wind erosion, whereas the predominant resource concern in the Ohio-Tennessee River Basin is phosphorus loss and the predominant resource concern in the Upper Mississippi River Basin is nitrogen loss in subsurface flows (table 67).

Sediment, nutrients, and atrazine loads delivered to rivers and streams from cultivated cropland are lower in the Missouri River Basin, on a per-acre basis, than in the other two regions (table 68). Percent reductions due to 2003–06 practice use in the Missouri River Basin are on a par with those in the other two regions for sediment and atrazine, but are higher for nitrogen and phosphorus, reflecting the higher level of nutrient management and lower annual precipitation within the Missouri River Basin. Potential percent reductions due to additional conservation treatment of under-treated acres are much lower in the Missouri River Basin than in the other two regions because the proportion of acres needing additional treatment is also much lower.

Instream loads delivered to the Lower Mississippi River Basin from each of the three water resource regions are contrasted in table 68. Sediment loads are highest for the Missouri River Basin in large part because of the streambank and bed erosion that occurs between Gavin's Point and the confluence with the Mississippi River. Nitrogen, phosphorus, and atrazine loads from the Missouri River Basin are lower than from the other two basins, in spite of the much larger crop acreage.

On a percentage basis, instream loads delivered to the Lower Mississippi that are attributable to cultivated cropland sources are generally comparable for the Missouri River Basin and the Upper Mississippi River Basin except for phosphorus (table 68). Only 32 percent of instream phosphorus loads delivered to the Lower Mississippi River are attributable to cultivated cropland in the Missouri River Basin, compared to 61 percent in the Upper Mississippi River Basin and 51 percent in the Ohio-Tennessee River Basin.

Percent reductions in instream loads (all sources) due to 2003-06 conservation practice use and due to additional conservation treatment are also contrasted among the three regions in table 68. These percentages are heavily influenced by the extent to which cultivated cropland is the source of contaminants in each basin, as well as the extent of conservation treatment within each basin.

Table 67. Comparison of conservation treatment needs among three of the five water resource regions that make up the Mississippi River drainage system

	Missouri River Basin			Upper Mississippi River Basin (revised) *	Ohio-Tennessee River Basin
	Western portion	Eastern portion	Entire basin		
Conservation treatment needs (percent of cropped acres)					
Sediment loss					
High level of treatment need	0	1	<1	10	14
Moderate level of treatment need	0	7	3	0	12
Under-treated (high or moderate level of treatment need)	0	8	3	10	25
Nitrogen lost with runoff					
High level of treatment need	0	1	<1	11	12
Moderate level of treatment need	0	8	3	12	16
Under-treated (high or moderate level of treatment need)	0	9	4	24	29
Nitrogen loss in subsurface flows					
High level of treatment need	<1	0	<1	3	2
Moderate level of treatment need	2	1	2	45	16
Under-treated (high or moderate level of treatment need)	3	1	2	47	17
Phosphorus lost to surface water					
High level of treatment need	0	1	<1	5	20
Moderate level of treatment need	0	1	<1	18	44
Under-treated (high or moderate level of treatment need)	0	2	1	22	63
Wind erosion					
High level of treatment need	<1	0	<1	0	0
Moderate level of treatment need	21	<1	12	0	0
Under-treated (high or moderate level of treatment need)	21	<1	12	0	0
One or more resource concern					
High level of treatment need	<1	2	1	15	24
Moderate level of treatment need	22	10	17	45	46
Under-treated (high or moderate level of treatment need)	23	12	18	60	70
Conservation treatment needs for one or more resource concerns (million acres)					
High level of treatment need	0.295	0.831	1.127	8.980	6.012
Moderate level of treatment need	10.464	3.715	14.179	26.218	11.506
Under-treated (high or moderate level of treatment need)	10.760	4.546	15.306	35.198	17.518

* Final estimates, revised December, 2010.

Table 68. Comparison of loads delivered from cultivated cropland to rivers and streams and instream loads (all sources) among three of the five water resource regions that make up the Mississippi River drainage system

	Missouri River Basin	Upper Mississippi River Basin (revised)*	Ohio-Tennessee River Basin
Loads delivered to rivers and streams from cultivated cropland			
Average annual amount per cultivated cropland acre, baseline conservation condition			
Sediment (tons/acre/year)	0.15	0.29	0.6
Nitrogen (pounds/acre/year)	5	16.5	19
Phosphorus (pounds/acre/year)	0.3	1.3	2.0
Atrazine (pounds/acre/year)	0.001	0.001	0.009
Percent of total loads delivered from all sources, baseline conservation condition			
Sediment	72	71	53
Nitrogen	68	714	49
Phosphorus	46	62	48
Atrazine	100	100	100
Percent reduction due to 2003–06 conservation practices			
Sediment	76	65	55
Nitrogen	54	26	26
Phosphorus	60	41	32
Atrazine	36	31	18
Percent reduction due to additional conservation treatment of cropped acres with a high or moderate treatment need			
Sediment	28	74	81
Nitrogen	13	49	41
Phosphorus	12	41	58
Atrazine	5	13	11
Instream loads from all sources at the outlet of the basin			
Baseline conservation condition			
Sediment (average annual 1,000 tons)	44,010	40,490	26,300
Nitrogen (average annual 1,000 pounds)	511,300	1,068,700	897,082
Phosphorus (average annual 1,000 pounds)	54,650	69,350	87,800
Atrazine (average annual 1,000 pounds)	61	141	178
Percent of total loads attributed to cultivated cropland sources, baseline conservation condition			
Sediment	22	22	20
Nitrogen	67	71	49
Phosphorus	32	61	51
Atrazine	100	100	100
Percent reduction in total loads due to 2003–06 conservation practice use on cultivated cropland acres			
Sediment	4	14	16
Nitrogen	36	19	15
Phosphorus	28	26	21
Atrazine	32	30	18
Percent reduction in total loads due to additional conservation treatment of cropped acres with a high or moderate treatment need			
Sediment	1	8	15
Nitrogen	6	33	20
Phosphorus	4	26	31
Atrazine	4	11	11

* Final estimates, revised December, 2010. Instream loads are for the Upper Mississippi River exclusive of loads delivered from the Missouri River.

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Appendix A: Estimates of Margins of Error for Selected Acre Estimates

The CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA/NRCS 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample. (Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap.)
The sample for cropped acres consists of 3,916 sample points in the Missouri River Basin. Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with statistical sampling.

Statistics derived from the CEAP database are based upon data collected at sample sites located across all parts of the region. This means that estimates of acreage are statistical estimates and contain some amount of statistical uncertainty. Since the NRI employs recognized statistical methodology, it is possible to quantify this statistical uncertainty.

Margins of error are provided in table A1 for selected acres estimates found elsewhere in the report. The margin of error is a commonly used measure of statistical uncertainty and can be used to construct a 95-percent confidence interval for an estimate. The lower bound of the confidence interval is obtained by subtracting the margin of error from the estimate; adding the margin of error to the estimate forms the upper bound. Measures of uncertainty (e.g., margins of error, standard errors, confidence intervals, coefficients of variation) should be taken into consideration when using CEAP acreage estimates. The margin of error is calculated by multiplying the standard error by the factor 1.96; a coefficient of variation is the relative standard for an estimate, usually in terms of percentages, and is calculated by taking 100 times the standard error and then dividing by the estimate.

The precision of CEAP acres estimates depends upon the number of samples within the region of interest, the distribution of the resource characteristics across the region, the sampling procedure, and the estimation procedure. Characteristics that are common and spread fairly uniformly over an area can be estimated more precisely than characteristics that are rare or unevenly distributed.

For reporting, results for some subregions were combined because of small sample sizes.

Table A1. Margins of error for acre estimates based on the CEAP sample

	Estimated acres	Margin of error
Cropping Systems (table 6)		
Corn-soybean only	27,057,241	1,227,360
Corn only	4,900,888	855,092
Corn-soybean with close grown crops	2,441,475	647,971
Corn and close grown crops	4,324,249	745,184
Soybean only	1,521,125	330,258
Soybean-wheat only	2,670,577	466,703
Wheat only	19,531,707	1,549,335
Sorghum-wheat and sorghum only	3,174,098	738,226
Sunflower and close grown crops	1,978,953	577,119
Vegetables with and without other crops	1,969,318	717,320
Hay-crop mix	4,579,875	695,073
Remaining mix of row and close-grown crops	6,326,943	965,026
Remaining mix of row crops	1,432,176	384,798
Remaining mix of close-grown crops	1,705,876	607,897
Use of structural practices (table 7)		
Overland flow control practices	26,921,998	1,567,305
Concentrated flow control practices	17,547,805	1,539,498
Edge-of-field buffering and filtering practices	2,643,903	643,948
One or more water erosion control practices	34,463,362	1,880,560
Wind erosion control practices	8,705,256	1,310,844
Use of cover crops	213,778	208,865

Table A1—continued.

	Estimated acres	Margin of error
Use of residue and tillage management (table 8)		
Average annual tillage intensity for crop rotation meets criteria for no-till	38,710,480	1,937,281
Average annual tillage intensity for crop rotation meets criteria for mulch till	38,904,183	1,827,706
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	3,350,031	739,361
Continuous conventional tillage in every year of crop rotation	2,649,805	618,600
Conservation treatment levels for structural practices (fig. 9)		
High level of treatment	1,563,590	461,588
Moderately high level of treatment	11,367,281	1,288,671
Moderate level of treatment	21,532,491	1,732,684
Low level of treatment	49,151,138	1,810,459
Conservation treatment levels for residue and tillage management (fig. 10)		
High level of treatment	43,440,691	1,942,717
Moderately high level of treatment	4,425,939	615,810
Moderate level of treatment	34,510,576	1,689,836
Low level of treatment	1,237,293	384,532
Conservation treatment levels for nitrogen management (fig. 11)		
High level of treatment	25,204,060	1,311,595
Moderately high level of treatment	29,088,599	1,625,682
Moderate level of treatment	23,605,328	1,456,329
Low level of treatment	5,716,512	791,200
Conservation treatment levels for phosphorus management (fig. 12)		
High level of treatment	40,066,291	1,522,257
Moderately high level of treatment	12,593,040	1,086,946
Moderate level of treatment	18,435,066	1,279,401
Low level of treatment	12,520,104	1,112,229
Conservation treatment levels for IPM (fig. 13)		
High level of treatment	5,952,625	847,535
Moderate level of treatment	36,618,099	2,108,398
Low level of treatment	41,043,776	1,735,149
Conservation treatment levels for water erosion control practices (fig. 64)		
High level of treatment	22,807,279	1,619,061
Moderately high level of treatment	14,493,487	1,011,691
Moderate level of treatment	36,082,081	1,683,130
Low level of treatment	10,231,654	1,127,848
Conservation treatment levels for nitrogen runoff control (fig. 65)		
High level of treatment	3,821,670	714,090
Moderately high level of treatment	37,961,313	1,693,849
Moderate level of treatment	38,396,773	1,601,978
Low level of treatment	3,434,744	662,099
Conservation treatment levels for phosphorus runoff control (fig. 66)		
High level of treatment	11,534,857	1,012,063
Moderately high level of treatment	31,785,076	1,968,363
Moderate level of treatment	33,311,036	1,899,813
Low level of treatment	6,983,530	967,734
Conservation treatment levels for wind erosion control (fig. 67)		
High level of treatment	6,727,749	1,260,099
Moderately high level of treatment	35,738,522	1,528,289
Moderate level of treatment	35,770,772	1,634,750
Low level of treatment	5,377,458	788,047

Table A1—continued.

	Estimated acres	Margin of error
Soil runoff potential (fig. 68)		
High	10,055,962	1,028,571
Moderately high	19,026,311	1,767,000
Moderate	9,988,901	1,044,900
Low	44,543,326	1,721,441
Soil leaching potential (fig. 70)		
High	4,125,269	677,246
Moderately high	5,080,508	979,802
Moderate	65,576,002	2,156,342
Low	8,832,721	1,009,763
Soil wind erosion potential (fig. 72)		
High	1,292,835	350,761
Moderately high	21,768,173	1,297,089
Moderate	34,997,946	1,746,516
Low	25,555,546	1,335,179
Level of conservation treatment need by resource concern		
Sediment loss (table 26)		
High (critical under-treated)	370,847	146,111
Moderate (non-critical under-treated)	2,485,278	555,130
Low (adequately treated)	80,758,375	1,782,030
Nitrogen loss with surface runoff (sediment attached and soluble) (table 27)		
High (critical under-treated)	395,560	126,689
Moderate (non-critical under-treated)	2,879,465	514,901
Low (adequately treated)	80,339,475	1,867,958
Nitrogen loss in subsurface flows (table 28)		
High (critical under-treated)	284,776	139,568
Moderate (non-critical under-treated)	1,553,636	499,229
Low (adequately treated)	81,776,088	1,895,278
Phosphorus lost to surface water (table 29)		
High (critical under-treated)	346,801	177,179
Moderate (non-critical under-treated)	380,734	246,516
Low (adequately treated)	82,886,965	1,855,614
Wind erosion (table 30)		
High (critical under-treated)	33,961	34,257
Moderate (non-critical under-treated)	10,299,223	1,178,784
Low (adequately treated)	73,281,316	2,130,809
Level of conservation treatment need for one or more resource concerns (table 35)		
Missouri River Basin		
High (critical under-treated)	1,126,701	234,366
Moderate (non-critical under-treated)	14,179,371	1,266,584
Low (adequately treated)	68,308,429	2,005,140
Missouri Headwaters and Upper Missouri-Marias (codes 1002,1003)		
High (critical under-treated)	0	0
Moderate (non-critical under-treated)	410,118	274,128
Low (adequately treated)	3,303,782	758,613
Missouri-Musselshell-Fort Peck Lake (code 1004)		
High (critical under-treated)	0	0
Moderate (non-critical under-treated)	456,266	254,698
Low (adequately treated)	778,634	412,042

Table A1—continued.

	Estimated acres	Margin of error
Level of conservation treatment need for one or more resource concerns--continued		
Milk River Basin (code 1005)		
High (critical under-treated)	0	0
Moderate (non-critical under-treated)	772,156	280,609
Low (adequately treated)	1,254,444	431,458
Missouri-Poplar River Basin (code 1006)		
High (critical under-treated)	32,301	66,388
Moderate (non-critical under-treated)	850,633	276,023
Low (adequately treated)	1,711,866	427,771
Upper Yellowstone River Basin (code 1007)		
High (critical under-treated)	0	0
Moderate (non-critical under-treated)	94,286	95,824
Low (adequately treated)	358,914	232,693
Big Horn and Powder-Tongue River Basins (codes 1008, 1009)		
High (critical under-treated)	0	0
Moderate (non-critical under-treated)	384,569	183,899
Low (adequately treated)	240,231	107,458
Lower Yellowstone River (code 1010)		
High (critical under-treated)	0	0
Moderate (non-critical under-treated)	503,954	237,142
Low (adequately treated)	373,046	296,653
Missouri-Little Missouri-Lake Sakakawea (code 1011)		
High (critical under-treated)	0	0
Moderate (non-critical under-treated)	442,437	253,129
Low (adequately treated)	2,235,963	376,252
Cheyenne and Missouri-Grand-Moreau-Lake Oahe (codes 1012, 1013)		
High (critical under-treated)	37,102	75,482
Moderate (non-critical under-treated)	789,769	430,035
Low (adequately treated)	6,238,729	832,900
Missouri-White River-Fort Randall Reservoir (code 1014)		
High (critical under-treated)	0	0
Moderate (non-critical under-treated)	21,953	27,006
Low (adequately treated)	2,630,647	351,790
Niobrara River Basin (code 1015)		
High (critical under-treated)	14,192	26,515
Moderate (non-critical under-treated)	378,800	208,015
Low (adequately treated)	762,208	194,741
James River Basin (code 1016)		
High (critical under-treated)	13,984	29,320
Moderate (non-critical under-treated)	642,163	375,434
Low (adequately treated)	6,468,354	506,490
Missouri-Big Sioux-Lewis-Clark Lake (code 1017)		
High (critical under-treated)	57,174	45,620
Moderate (non-critical under-treated)	235,645	86,321
Low (adequately treated)	5,392,080	394,204
North Platte River Basin (code 1018)		
High (critical under-treated)	0	0
Moderate (non-critical under-treated)	740,067	232,378
Low (adequately treated)	246,133	172,821

Table A1—continued.

	Estimated acres	Margin of error
Level of conservation treatment need for one or more resource concerns--continued		
South Platte River Basin **(code 1019)**		
High (critical under-treated)	43,294	40,283
Moderate (non-critical under-treated)	1,845,275	408,073
Low (adequately treated)	1,415,931	331,708
Middle and Lower Platte River Basin **(code 1020)**		
High (critical under-treated)	30,315	43,514
Moderate (non-critical under-treated)	450,020	216,699
Low (adequately treated)	2,048,065	308,022
Loup River Basin **(code 1021)**		
High (critical under-treated)	12,453	27,249
Moderate (non-critical under-treated)	155,061	119,634
Low (adequately treated)	1,330,186	325,715
Elkhorn River Basin **(code 1022)**		
High (critical under-treated)	21,444	31,425
Moderate (non-critical under-treated)	576,129	246,336
Low (adequately treated)	1,740,527	337,643
Missouri-Little Sioux River Basin **(code 1023)**		
High (critical under-treated)	118,496	133,681
Moderate (non-critical under-treated)	525,881	230,591
Low (adequately treated)	3,896,723	626,940
Missouri-Nishnabotna River Basin **(code 1024)**		
High (critical under-treated)	185,993	90,045
Moderate (non-critical under-treated)	841,736	222,082
Low (adequately treated)	4,179,870	541,248
Republican River Basin (code 1025)		
High (critical under-treated)	125,666	94,816
Moderate (non-critical under-treated)	1,877,322	541,945
Low (adequately treated)	5,887,812	707,692
Smoky Hill River Basin **(code 1026)**		
High (critical under-treated)	0	0
Moderate (non-critical under-treated)	379,030	400,681
Low (adequately treated)	6,767,270	774,416
Kansas-Big Blue River Basin **(code 1027)**		
High (critical under-treated)	95,206	76,342
Moderate (non-critical under-treated)	253,961	105,026
Low (adequately treated)	4,520,734	449,470
Chariton-Grand River Basin **(code 1028)**		
High (critical under-treated)	222,719	117,847
Moderate (non-critical under-treated)	240,529	105,773
Low (adequately treated)	1,594,852	237,276
Gasconade-Osage River Basin **(code 1029)**		
High (critical under-treated)	26,011	32,363
Moderate (non-critical under-treated)	105,039	75,891
Low (adequately treated)	1,370,850	288,045
Lower Missouri-Lower Missouri-Blackwater **(code 1030)**		
High (critical under-treated)	90,349	66,398
Moderate (non-critical under-treated)	206,571	102,261
Low (adequately treated)	1,560,580	154,130

Appendix B: Model Simulation Results for the Baseline Conservation Condition for Subregions in the Missouri River Basin

Model simulation results presented in Chapter 4 for the baseline conservation condition are presented in tables B1–B5 for the subregions in the Missouri River Basin. For reporting, results for some subregions were combined because of small sample sizes. The column headings refer to the 4-digit Hydrologic Unit Codes (HUC), as shown below:

Subregion code	Subregion name
1002 and 1003	Missouri Headwaters and Upper Missouri-Marias Basins
1004	Missouri-Musselshell-Fort Peck Lake
1005	Milk River Basin
1006	Missouri-Poplar River Basin
1007	Upper Yellowstone River Basin
1008 and 1009	Big Horn and Powder-Tongue River Basins
1010	Lower Yellowstone River Basin
1011	Missouri-Little Missouri-Lake Sakakawea Basin
1012 and 1013	Cheyenne River and Missouri-Grand-Moreau-Lake Oahe Basins
1014	Missouri-White River-Fort Randall Reservoir Basin
1015	Niobrara River Basin
1016	James River Basin
1017	Missouri-Big Sioux-Lewis-Clark Lake Basin
1018	North Platte River Basin
1019	South Platte River Basin
1020	Middle and Lower Platte River Basin
1021	Loup River Basin
1022	Elkhorn River Basin
1023	Missouri-Little Sioux River Basin
1024	Missouri-Nishnabotna River Basin
1025	Republican River Basin
1026	Smoky Hill River Basin
1027	Kansas-Big Blue River Basin
1028	Chariton-Grand River Basin
1029	Gasconade-Osage River Basin

Table B1. Basin characteristics and average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subregion, in the Missouri River Basin

Model simulated outcome	Missouri River Basin	1002 and 1003	1004	1005	1006	1007	1008 and 1009	1010	1011	1012 and 1013	1014
CEAP sample size for estimating cropped acres	3,916	93	48	51	114	30	37	43	93	202	109
Cropped acres (million acres)	83.615	3.714	1.235	2.027	2.595	0.453	0.625	0.877	2.678	7.066	2.653
Percent of acres in region	100.0	4.4	1.5	2.4	3.1	0.5	0.7	1.0	3.2	8.5	3.2
Percent of acres highly erodible	40	83	73	99	82	59	44	55	38	41	42
Percent of acres irrigated	14	12	12	4	1	24	47	13	0.00	2	2
Percent of acres receiving manure	5	1	2	0.00	0.00	8	3	10	0.00	4	4
Water sources (average annual inches)											
Non-irrigated acres											
Precipitation	23	14	15	12	13	16	15	14	15	17	20
Irrigated acres											
Precipitation	23	19	18	11	13	17	13	13	NA	17	21
Irrigation water applied	13	9	11	14	12	16	16	19	NA	12	12
Water loss pathways (average annual inches)											
Evapotranspiration	20.0	13.3	14.8	11.8	12.3	16.1	17.1	14.4	14.7	15.9	18.2
Surface water runoff	1.3	1.0	0.6	0.3	0.3	1.2	0.8	0.4	0.4	0.4	0.6
Subsurface water flow	3.1	1.4	1.3	0.2	0.6	2.0	2.1	0.8	0.3	0.7	1.4
Erosion and sediment loss (average annual tons/acre)											
Wind erosion	1.13	0.86	1.99	1.79	1.52	2.50	1.68	3.91	1.13	0.97	1.12
Sheet and rill erosion	0.31	0.03	0.02	0.03	0.02	0.06	0.01	0.01	0.01	0.04	0.13
Sediment loss at edge of field due to water erosion	0.26	0.09	0.07	0.04	0.06	0.25	0.13	0.10	0.06	0.06	0.09
Soil organic carbon (average annual pounds/acre)											
Loss of soil organic carbon with wind and water erosion	133	67	82	89	80	131	73	126	94	88	115
Change in soil organic carbon, including loss of carbon with wind and water erosion	52	-9	-44	-92	-85	-90	5	-137	-47	-2	20

Table B1—continued. Basin characteristics and average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subregion, in the Missouri River Basin

Model simulated outcome	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025
CEAP sample size for estimating cropped acres	46	267	414	44	154	143	65	103	230	380	330
Cropped acres (million acres)	1.155	7.124	5.685	0.986	3.305	2.528	1.498	2.338	4.541	5.208	7.891
Percent of acres in region	1.4	8.5	6.8	1.2	4.0	3.0	1.8	2.8	5.4	6.2	9.4
Percent of acres highly erodible	37	16	20	67	56	22	22	31	38	56	30
Percent of acres irrigated	45	1	3	41	22	62	69	30	7	1	26
Percent of acres receiving manure	1	6	16	6	6	6	13	9	16	4	4
Water sources (average annual inches)											
Non-irrigated acres											
Precipitation	20	20	25	16	16	28	24	28	29	34	20
Irrigated acres											
Precipitation	21	23	25	16	16	25	24	26	29	33	21
Irrigation water applied	12	14	11	16	14	14	13	12	11	11	13
Water loss pathways (average annual inches)											
Evapotranspiration	20.2	18.1	21.2	18.3	17.3	25.0	24.1	23.6	23.8	24.8	20.6
Surface water runoff	0.5	0.7	1.2	0.4	0.2	1.8	1.1	1.5	1.9	3.1	0.4
Subsurface water flow	3.9	1.9	3.2	2.7	1.2	8.0	6.4	4.9	4.5	6.0	2.4
Erosion and sediment loss (average annual tons/acre)											
Wind erosion	0.71	0.98	0.67	2.30	4.75	0.61	0.46	0.37	0.44	0.13	2.24
Sheet and rill erosion	0.09	0.06	0.16	0.02	0.01	0.27	0.15	0.38	0.49	1.09	0.12
Sediment loss at edge of field due to water erosion	0.06	0.05	0.13	0.06	0.02	0.29	0.19	0.35	0.36	0.87	0.07
Soil organic carbon (average annual pounds/acre)											
Loss of soil organic carbon with wind and water erosion	72	137	129	106	203	165	101	144	149	196	151
Change in soil organic carbon, including loss of carbon with wind and water erosion	46	60	170	-37	-131	209	226	201	224	168	-9

Table B1—continued. Basin characteristics and average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subregion, in the Missouri River Basin

Model simulated outcome	1026	1027	1028	1029	1030
CEAP sample size for estimating cropped acres	162	335	157	107	159
Cropped acres (million acres)	7.146	4.870	2.058	1.502	1.858
Percent of acres in region	8.5	5.8	2.5	1.8	2.2
Percent of acres highly erodible	30	27	46	28	36
Percent of acres irrigated	9	44	0.06	6	0.00
Percent of acres receiving manure	2	4	4	3	4
Water sources (average annual inches)					
Non-irrigated acres					
Precipitation	23	31	36	40	39
Irrigated acres					
Precipitation	20	28	37	42	NA
Irrigation water applied	11	12	5	8	NA
Water loss pathways (average annual inches)					
Evapotranspiration	21.4	25.6	25.0	26.9	26.3
Surface water runoff	0.5	2.6	4.7	6.6	6.0
Subsurface water flow	1.8	6.8	6.8	7.8	8.0
Erosion and sediment loss (average annual tons/acre)					
Wind erosion	1.05	0.25	0.13	0.18	0.07
Sheet and rill erosion	0.18	0.80	1.35	1.43	1.60
Sediment loss at edge of field due to water erosion	0.09	0.55	1.31	1.22	1.35
Soil organic carbon (average annual pounds/acre)					
Loss of soil organic carbon with wind and water erosion	87	163	232	219	241
Change in soil organic carbon, including loss of carbon with wind and water erosion	-11	164	70	6	60

Table B2. Average annual estimates of nitrogen loss for the baseline conservation condition for cropped acres, by subregion, in the Missouri River Basin

Model simulated outcome	Missouri River Basin	1002 and 1003	1004	1005	1006	1007	1008 and 1009	1010	1011	1012 and 1013	1014
Nitrogen (average annual pounds/acre)											
Nitrogen sources											
Atmospheric deposition	4.9	1.3	1.7	1.4	2.1	1.6	1.7	2.1	2.4	3.1	4.6
Bio-fixation by legumes	31.2	4.1	11.9	0.0	1.1	5.5	16.8	8.0	7.0	6.3	17.3
Nitrogen applied as commercial fertilizer and manure	65.4	42.5	43.3	27.9	41.5	56.6	78.6	37.6	46.5	63.9	56.6
All nitrogen sources	101.5	48.0	56.9	29.4	44.6	63.7	97.1	47.7	56.0	73.2	78.6
Nitrogen in crop yield removed at harvest	76.4	39.3	49.7	28.2	35.7	51.5	71.5	43.8	46.4	56.5	56.3
Nitrogen loss pathways											
Nitrogen loss by volatilization	6.3	4.7	4.6	4.0	5.7	3.5	4.7	4.3	5.4	5.9	8.1
Nitrogen loss through denitrification	1.8	0.8	1.4	0.6	1.1	1.5	0.8	0.4	0.6	2.3	1.5
Nitrogen lost with windborne sediment	5.8	4.1	5.9	7.0	6.0	8.7	4.8	10.3	6.2	5.3	6.8
Nitrogen loss with surface runoff , including waterborne sediment	2.6	1.2	1.0	0.6	0.5	2.0	1.2	0.5	0.5	0.6	1.5
Nitrogen loss in subsurface flow pathways	6.9	4.8	3.7	1.7	2.5	7.5	14.0	2.8	1.5	3.6	3.8
Total nitrogen loss for all loss pathways	23.4	15.6	16.7	13.9	15.7	23.2	25.5	18.3	14.3	17.6	21.7
Change in soil nitrogen	0.8	-7.4	-10.0	-13.1	-7.3	-11.4	-0.4	-14.9	-5.4	-1.6	-0.3

Table B2--continued. Average annual estimates of nitrogen loss for the baseline conservation condition for cropped acres, by subregion, in the Missouri River Basin

Model simulated outcome	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025
Nitrogen (average annual pounds/acre)											
Nitrogen sources											
Atmospheric deposition	4.6	4.8	6.3	3.3	3.4	6.4	5.8	6.7	7.4	7.8	4.5
Bio-fixation by legumes	21.5	38.3	53.8	5.3	2.8	44.4	44.5	66.3	66.6	72.2	9.6
Nitrogen applied as commercial fertilizer and manure	81.7	62.7	76.6	69.6	50.2	107.6	114.6	89.4	79.8	70.6	69.2
All nitrogen sources	107.7	105.8	136.8	78.2	56.3	158.4	165.0	162.5	153.8	150.6	83.4
Nitrogen in crop yield removed at harvest	82.4	79.7	98.2	56.8	40.2	116.1	119.8	117.0	113.0	113.2	60.0
Nitrogen loss pathways											
Nitrogen loss by volatilization	6.5	8.2	7.5	5.7	5.3	6.7	7.8	7.9	6.7	6.8	6.5
Nitrogen loss through denitrification	1.4	1.0	2.7	0.6	0.7	3.8	3.7	3.5	3.5	2.6	1.4
Nitrogen lost with windborne sediment	3.7	7.8	6.0	7.5	15.9	5.7	3.5	3.9	3.9	1.5	9.7
Nitrogen loss with surface runoff , including waterborne sediment	0.5	0.7	1.5	0.4	0.2	3.0	1.8	3.6	4.1	8.3	0.8
Nitrogen loss in subsurface flow pathways	10.4	6.6	8.5	10.4	6.2	10.3	11.7	14.0	8.2	9.9	6.8
Total nitrogen loss for all loss pathways	22.4	24.3	26.2	24.6	28.3	29.4	28.5	32.8	26.3	29.1	25.2
Change in soil nitrogen	2.2	0.8	11.2	-3.9	-13.0	12.0	15.9	11.7	13.2	7.2	-2.6

Table B2--continued. Average annual estimates of nitrogen loss for the baseline conservation condition for cropped acres, by subregion, in the Missouri River Basin

Model simulated outcome	1026	1027	1028	1029	1030
Nitrogen (average annual pounds/acre)					
Nitrogen sources					
Atmospheric deposition	5.0	6.6	7.7	7.2	7.2
Bio-fixation by legumes	3.4	55.8	84.5	79.4	80.5
Nitrogen applied as commercial fertilizer and manure	52.9	84.9	56.3	59.1	68.1
All nitrogen sources	61.3	147.3	148.4	145.6	155.8
Nitrogen in crop yield removed at harvest	45.6	113.6	116.7	118.3	120.5
Nitrogen loss pathways					
Nitrogen loss by volatilization	5.5	6.0	6.2	6.0	6.1
Nitrogen loss through denitrification	0.6	2.2	2.9	1.7	2.2
Nitrogen lost with windborne sediment	5.3	2.9	1.3	1.3	0.6
Nitrogen loss with surface runoff , including waterborne sediment	0.9	5.4	11.1	10.7	12.2
Nitrogen loss in subsurface flow pathways	4.9	8.6	9.1	10.4	13.0
Total nitrogen loss for all loss pathways	17.3	25.2	30.6	30.0	34.0
Change in soil nitrogen	-2.4	7.7	0.1	-3.3	0.3

Table B3. Average annual estimates of phosphorus loss and pesticide loss for the baseline conservation condition for cropped acres, by subregion, in the Missouri River Basin

Model simulated outcome	Missouri River Basin	1002 and 1003	1004	1005	1006	1007	1008 and 1009	1010	1011	1012 and 1013	1014
Phosphorus (average annual pounds/acre)											
Phosphorus applied as commercial fertilizer and manure	14.2	7.7	8.0	4.6	7.8	14.5	15.3	8.0	6.9	10.8	10.6
Phosphorus in crop yield removed at harvest	11.9	5.1	5.9	3.8	4.7	8.0	9.7	6.1	6.4	7.9	8.5
Phosphorus loss pathways											
Phosphorus lost with windborne sediment	1.0	0.8	1.1	1.2	1.0	2.3	1.1	2.4	0.9	0.8	0.9
Phosphorus lost to surface water, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage tiles and ditches and natural seeps	0.7	0.3	0.3	0.1	0.1	0.7	0.3	0.1	0.1	0.2	0.3
Soluble phosphorus loss to groundwater	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total phosphorus loss for all loss pathways	1.7	1.1	1.4	1.3	1.1	2.9	1.5	2.5	1.0	1.0	1.2
Change in soil phosphorus	0.5	1.5	0.7	-0.5	2.0	3.6	4.1	-0.7	-0.5	1.9	0.9
Pesticides											
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1027	629	381	508	736	599	3669	506	592	576	733
Pesticide loss											
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	3.4	0.4	0.1	0.3	0.1	0.8	2.0	0.6	0.1	0.2	0.9
Edge-of-field pesticide risk indicator											
Average annual surface water pesticide risk indicator for aquatic ecosystem	1.33	1.37	0.46	1.79	0.21	0.28	5.18	0.98	0.13	0.35	0.50
Average annual surface water pesticide risk indicator for humans	0.26	0.05	0.01	0.06	0.03	0.02	0.54	0.06	0.01	0.04	0.08
Average annual groundwater pesticide risk indicator for humans	0.06	0.01	<0.01	0.01	<0.01	0.04	0.80	0.02	<0.01	<0.01	<0.01

Table B3--continued. Average annual estimates of phosphorus loss and pesticide loss for the baseline conservation condition for cropped acres, by subregion, in the Missouri River Basin

Model simulated outcome	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025
Phosphorus (average annual pounds/acre)											
Phosphorus applied as commercial fertilizer and manure	13.3	14.9	20.6	12.6	7.2	22.6	24.6	23.8	22.1	19.5	11.8
Phosphorus in crop yield removed at harvest	13.6	12.1	15.6	10.0	6.5	20.4	20.2	19.3	18.3	17.9	9.9
Phosphorus loss pathways											
Phosphorus lost with windborne sediment	0.7	1.3	1.1	1.3	3.0	1.0	0.7	0.7	0.7	0.3	2.0
Phosphorus lost to surface water, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage tiles and ditches and natural seeps	0.2	0.2	0.5	0.2	0.1	0.7	0.5	1.0	1.1	2.1	0.2
Soluble phosphorus loss to groundwater	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total phosphorus loss for all loss pathways	0.9	1.5	1.7	1.5	3.0	1.8	1.2	1.7	1.8	2.4	2.2
Change in soil phosphorus	-1.3	1.3	3.3	1.1	-2.5	0.2	3.1	2.7	1.8	-1.1	-0.3
Pesticides											
Average annual amount of pesticides applied (grams of active ingredient/hectare)	842	1091	1251	301	571	1825	1588	1479	1442	1526	863
Pesticide loss											
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	1.4	0.7	1.1	0.2	0.2	6.2	3.9	3.8	4.4	12.0	0.8
Edge-of-field pesticide risk indicator											
Average annual surface water pesticide risk indicator for aquatic ecosystem	0.61	0.37	0.41	0.15	0.76	2.25	1.69	0.85	1.91	2.37	1.00
Average annual surface water pesticide risk indicator for humans	0.18	0.09	0.06	0.04	0.12	0.40	0.42	0.19	0.25	0.58	0.17
Average annual groundwater pesticide risk indicator for humans	0.12	0.01	0.01	0.03	0.07	0.18	0.29	0.09	0.06	0.12	0.08

Table B3--continued. Average annual estimates of phosphorus loss and pesticide loss for the baseline conservation condition for cropped acres, by subregion, in the Missouri River Basin

Model simulated outcome	1026	1027	1028	1029	1030
Phosphorus (average annual pounds/acre)					
Phosphorus applied as commercial fertilizer and manure	8.0	18.5	19.1	18.2	19.7
Phosphorus in crop yield removed at harvest	7.1	18.3	17.5	17.6	18.2
Phosphorus loss pathways					
Phosphorus lost with windborne sediment	0.8	0.5	0.3	0.3	0.1
Phosphorus lost to surface water, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage tiles and ditches and natural seeps	0.2	1.2	2.9	2.9	3.0
Soluble phosphorus loss to groundwater	<0.1	<0.1	<0.1	<0.1	<0.1
Total phosphorus loss for all loss pathways	1.0	1.8	3.2	3.3	3.1
Change in soil phosphorus	-0.2	-1.8	-1.8	-2.8	-1.8
Pesticides					
Average annual amount of pesticides applied (grams of active ingredient/hectare)	659	1644	1290	1112	1455
Pesticide loss					
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	0.8	9.1	14.6	13.2	20.7
Edge-of-field pesticide risk indicator					
Average annual surface water pesticide risk indicator for aquatic ecosystem	2.58	2.67	2.56	1.93	3.24
Average annual surface water pesticide risk indicator for humans	0.71	0.57	0.65	0.56	0.86
Average annual groundwater pesticide risk indicator for humans	0.02	0.11	0.07	0.07	0.10

Table B4. Percent of cropped acres for conservation treatment levels and soil vulnerability potentials, by subregion, in the Missouri River Basin

Model simulated outcome	Missouri River Basin	1002 and 1003	1004	1005	1006	1007	1008 and 1009	1010	1011	1012 and 1013	1014
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 9)											
High conservation treatment level	2	0	0	0	<1	0	0	1	0	1	1
Moderately-high conservation treatment level	14	1	0	0	8	6	5	5	0	6	2
Moderate conservation treatment level	26	34	33	31	27	40	1	16	17	19	24
Low conservation treatment level	59	65	67	69	65	54	94	78	83	74	73
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 10)											
High conservation treatment level	52	40	32	20	18	31	18	<1	27	46	50
Moderately-high conservation treatment level	5	3	13	0	0	0	13	4	1	3	5
Moderate conservation treatment level	41	55	55	80	82	69	66	95	72	51	44
Low conservation treatment level	1	1	0	0	0	0	3	<1	1	0	0
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 11)											
High conservation treatment level	30	53	67	71	58	30	54	62	55	46	27
Moderately-high conservation treatment level	35	36	20	16	17	46	27	30	24	21	26
Moderate conservation treatment level	28	10	11	11	20	17	18	5	21	29	35
Low conservation treatment level	7	1	2	2	5	7	1	3	1	4	12
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 12)											
High conservation treatment level	48	34	49	32	31	16	57	29	67	47	50
Moderately-high conservation treatment level	15	4	2	1	1	10	10	19	3	4	12
Moderate conservation treatment level	22	53	42	68	63	49	20	38	28	41	22
Low conservation treatment level	15	9	7	0	4	25	13	14	2	7	17
Percent of cropped acres within subregion at four conservation treatment levels of soil runoff potential (see figure 68)											
High conservation treatment level	12	8	16	4	23	22	8	8	6	6	13
Moderately-high conservation treatment level	23	57	42	68	33	46	39	35	12	26	44
Moderate conservation treatment level	12	6	8	2	4	8	7	1	31	23	9
Low conservation treatment level	53	29	33	26	39	24	46	56	51	45	34
Percent of cropped acres within subregion at four conservation treatment levels of soil leaching potential (see figure 70)											
High conservation treatment level	5	6	9	<1	5	0	9	2	4	7	1
Moderately-high conservation treatment level	6	30	17	47	13	8	17	17	4	11	2
Moderate conservation treatment level	78	54	64	50	80	70	64	80	86	74	60
Low conservation treatment level	11	10	10	2	2	22	10	1	7	8	37
Percent of cropped acres within subregion at four conservation treatment levels of soil wind erosion potential (see figure 72)											
High conservation treatment level	2	0	0	0	0	0	0	0	0	3	<1
Moderately-high conservation treatment level	26	70	56	100	100	40	86	100	53	26	12
Moderate conservation treatment level	42	27	44	<1	0	60	14	0	47	71	88
Low conservation treatment level	31	4	0	0	0	0	0	0	0	0	0

Table B4--continued. Percent of cropped acres for conservation treatment levels and soil vulnerability potentials, by subregion, in the Missouri River Basin

Model simulated outcome	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 9)											
High conservation treatment level	0	1	2	0	0	1	3	0	8	6	1
Moderately-high conservation treatment level	0	3	6	2	1	19	5	14	25	42	8
Moderate conservation treatment level	26	16	25	33	38	11	16	16	29	33	30
Low conservation treatment level	74	81	67	65	62	69	76	70	38	19	62
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 10)											
High conservation treatment level	52	68	81	12	11	86	85	90	77	83	34
Moderately-high conservation treatment level	3	2	7	14	1	3	4	5	12	2	9
Moderate conservation treatment level	45	28	12	71	85	11	11	4	11	14	55
Low conservation treatment level	0	2	<1	3	3	1	0	0	0	0	3
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 11)											
High conservation treatment level	46	26	16	57	56	15	6	16	5	17	23
Moderately-high conservation treatment level	18	35	43	13	15	52	57	55	48	44	35
Moderate conservation treatment level	35	30	32	26	25	27	22	22	36	26	34
Low conservation treatment level	1	9	9	4	5	6	14	7	10	13	8
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 12)											
High conservation treatment level	80	48	43	75	70	69	51	42	34	41	50
Moderately-high conservation treatment level	8	12	18	4	8	18	30	26	23	31	12
Moderate conservation treatment level	7	24	11	15	15	3	3	6	7	5	18
Low conservation treatment level	5	16	27	6	7	9	16	26	35	23	19
Percent of cropped acres within subregion at four conservation treatment levels of soil runoff potential (see figure 68)											
High conservation treatment level	6	5	6	7	5	12	14	26	30	43	3
Moderately-high conservation treatment level	7	8	18	8	14	12	8	21	12	15	12
Moderate conservation treatment level	2	21	12	9	11	11	0	5	21	18	3
Low conservation treatment level	85	67	64	76	70	65	78	48	37	24	82
Percent of cropped acres within subregion at four conservation treatment levels of soil leaching potential (see figure 70)											
High conservation treatment level	29	4	1	16	11	16	20	17	<1	<1	8
Moderately-high conservation treatment level	3	3	1	8	12	2	3	0	0	0	4
Moderate conservation treatment level	64	86	90	69	76	73	77	71	82	79	88
Low conservation treatment level	4	8	8	6	2	9	<1	13	18	21	1
Percent of cropped acres within subregion at four conservation treatment levels of soil wind erosion potential (see figure 72)											
High conservation treatment level	11	1	<1	17	7	0	6	2	0	0	5
Moderately-high conservation treatment level	36	17	5	66	69	22	6	8	9	0	28
Moderate conservation treatment level	53	82	55	17	24	34	78	29	39	0	49
Low conservation treatment level	0	0	40	<1	<1	44	10	62	52	100	18

Table B4--continued. Percent of cropped acres for conservation treatment levels and soil vulnerability potentials, by subregion, in the Missouri River Basin

Model simulated outcome	1026	1027	1028	1029	1030
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 9)					
High conservation treatment level	1	4	6	1	8
Moderately-high conservation treatment level	29	36	24	26	27
Moderate conservation treatment level	41	13	26	29	32
Low conservation treatment level	29	48	45	43	33
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 10)					
High conservation treatment level	19	78	71	48	63
Moderately-high conservation treatment level	11	7	2	3	6
Moderate conservation treatment level	63	14	26	46	31
Low conservation treatment level	7	1	<1	2	<1
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 11)					
High conservation treatment level	24	11	27	23	19
Moderately-high conservation treatment level	29	53	40	44	38
Moderate conservation treatment level	43	27	24	29	33
Low conservation treatment level	4	9	8	5	10
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 12)					
High conservation treatment level	47	64	35	45	40
Moderately-high conservation treatment level	14	24	38	29	30
Moderate conservation treatment level	27	7	6	7	6
Low conservation treatment level	12	6	22	19	24
Percent of cropped acres within subregion at four conservation treatment levels of soil runoff potential (see figure 68)					
High conservation treatment level	5	10	30	1	17
Moderately-high conservation treatment level	16	33	28	51	34
Moderate conservation treatment level	2	8	18	22	13
Low conservation treatment level	77	49	24	26	37
Percent of cropped acres within subregion at four conservation treatment levels of soil leaching potential (see figure 70)					
High conservation treatment level	<1	<1	0	0	1
Moderately-high conservation treatment level	0	1	1	0	1
Moderate conservation treatment level	97	79	70	62	78
Low conservation treatment level	3	20	29	38	20
Percent of cropped acres within subregion at four conservation treatment levels of soil wind erosion potential (see figure 72)					
High conservation treatment level	0	0	0	0	0
Moderately-high conservation treatment level	6	0	0	0	0
Moderate conservation treatment level	76	2	0	0	0
Low conservation treatment level	18	98	100	100	100

Note: Percents may not add to 100 within categories due to rounding.

Table B5. Percent of cropped acres for conservation treatment needs, by subregion, in the Missouri River Basin

Model simulated outcome	Missouri River Basin	1002 and 1003	1004	1005	1006	1007	1008 and 1009	1010	1011	1012 and 1013	1014
Percent of cropped acres within subregion with conservation treatment needs for sediment loss											
High level of treatment need	<1	0	0	0	0	0	0	0	0	0	0
Moderate level of treatment need	3	0	0	0	0	0	0	0	0	0	0
Under-treated (high or moderate level of treatment need)	3	0	0	0	0	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff											
High level of treatment need	<1	0	0	0	0	0	0	0	0	0	0
Moderate level of treatment need	3	0	0	0	0	0	0	0	0	0	0
Under-treated (high or moderate level of treatment need)	4	0	0	0	0	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for phosphorus lost to surface water											
High level of treatment need	<1	0	0	0	0	0	0	0	0	0	0
Moderate level of treatment need	<1	0	0	0	0	0	0	0	0	0	0
Under-treated (high or moderate level of treatment need)	1	0	0	0	0	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows											
High level of treatment need	<1	0	0	0	1	0	0	0	0	1	0
Moderate level of treatment need	2	2	2	0	1	0	3	0	0	<1	1
Under-treated (high or moderate level of treatment need)	2	2	2	0	2	0	3	0	0	1	1
Percent of cropped acres within subregion with conservation treatment needs for wind erosion											
High level of treatment need	<1	0	0	0	0	0	0	0	0	0	0
Moderate level of treatment need	12	9	35	38	32	21	62	57	17	11	<1
Under-treated (high or moderate level of treatment need)	12	9	35	38	32	21	62	57	17	11	<1
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern											
High level of treatment need	1	0	0	0	1	0	0	0	0	1	0
Moderate level of treatment need	17	11	37	38	33	21	62	57	17	11	1
Under-treated (high or moderate level of treatment need)	18	11	37	38	34	21	62	57	17	12	1

Table B5--continued. Percent of cropped acres for conservation treatment needs, by subregion, in the Missouri River Basin

Model simulated outcome	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025
Percent of cropped acres within subregion with conservation treatment needs for sediment loss											
High level of treatment need	0	0	1	0	0	0	0	<1	<1	2	0
Moderate level of treatment need	0	6	3	0	0	2	0	13	5	9	0
Under-treated (high or moderate level of treatment need)	0	6	4	0	0	2	0	14	6	11	0
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff											
High level of treatment need	0	<1	1	0	0	0	0	0	1	1	0
Moderate level of treatment need	0	3	3	0	0	2	0	14	10	17	0
Under-treated (high or moderate level of treatment need)	0	3	4	0	0	2	0	14	11	18	0
Percent of cropped acres within subregion with conservation treatment needs for phosphorus lost to surface water											
High level of treatment need	0	0	<1	0	0	0	0	<1	2	3	0
Moderate level of treatment need	0	2	<1	0	0	0	0	2	1	0	0
Under-treated (high or moderate level of treatment need)	0	2	<1	0	0	0	0	2	2	3	0
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows											
High level of treatment need	1	0	0	0	1	1	1	0	0	0	2
Moderate level of treatment need	14	2	1	8	5	4	6	8	<1	<1	4
Under-treated (high or moderate level of treatment need)	15	2	1	8	6	5	7	8	<1	<1	6
Percent of cropped acres within subregion with conservation treatment needs for wind erosion											
High level of treatment need	0	0	0	0	<1	0	0	0	0	0	<1
Moderate level of treatment need	21	2	0	75	55	13	7	0	2	0	24
Under-treated (high or moderate level of treatment need)	21	2	0	75	55	13	7	0	2	0	25
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern											
High level of treatment need	1	<1	1	0	1	1	1	1	3	4	2
Moderate level of treatment need	33	9	4	75	56	18	10	25	12	16	24
Under-treated (high or moderate level of treatment need)	34	9	5	75	57	19	11	26	14	20	25

Table B5. Percent of cropped acres for conservation treatment needs, by subregion, in the Missouri River Basin

Model simulated outcome	1026	1027	1028	1029	1030
Percent of cropped acres within subregion with conservation treatment needs for sediment loss					
High level of treatment need	0	1	6	1	0
Moderate level of treatment need	0	4	16	6	12
Under-treated (high or moderate level of treatment need)	0	6	22	7	12
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff					
High level of treatment need	0	2	4	2	3
Moderate level of treatment need	0	4	18	1	8
Under-treated (high or moderate level of treatment need)	0	6	22	2	11
Percent of cropped acres within subregion with conservation treatment needs for phosphorus lost to surface water					
High level of treatment need	0	<1	3	0	2
Moderate level of treatment need	0	<1	2	4	3
Under-treated (high or moderate level of treatment need)	0	1	5	4	5
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows					
High level of treatment need	0	0	0	0	0
Moderate level of treatment need	<1	<1	0	0	1
Under-treated (high or moderate level of treatment need)	<1	<1	0	0	1
Percent of cropped acres within subregion with conservation treatment needs for wind erosion					
High level of treatment need	0	0	0	0	0
Moderate level of treatment need	5	0	0	0	0
Under-treated (high or moderate level of treatment need)	5	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern					
High level of treatment need	0	2	11	2	5
Moderate level of treatment need	5	5	12	7	11
Under-treated (high or moderate level of treatment need)	5	7	23	9	16